

4th International Conference on Industrial Engineering (ICIE-2017)



December 21–23, 2017

Editors: Dr. Ravi Kant | Dr. Tushar N. Desai | Dr. Bhaskar M. Bhandarkar

Organized by



**Department of Mechanical Engineering,
S. V. National Institute of Technology, Surat**

In Association with



**Indian Institution of Industrial
Engineering (IIIE), NHQ-Mumbai**

Supported by

**L & T Heavy Engineering, Hazira, Surat
SVNIT Alumni Association, Surat Chapter, SVNIT, Surat
Swapn Preeti Bhadrash Shah Foundation, Surat**

PROCEEDINGS

**4th International Conference on
Industrial Engineering
ICIE 2017**

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Editors

**Dr. Ravi Kant
Dr. Tushar N. Desai
Dr. Bhaskar M. Bhandarkar**

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Director's Message



I am very much delighted to note that Department of Mechanical Engineering of Sardar Vallabhbhai National Institute of Technology (SVNIT) Surat is organizing *4th International Conference on Industrial Engineering (ICIE 2017)* which is scheduled to be held during December 21-23, 2017. This conference is organized in association with *Indian Institute of Industrial Engineering (IIIE), National Headquarters, Mumbai.*

ICIE 2017 is concerned with most recent development in the field of industrial engineering. The present three-day conference is designed to provide a common platform to the experts and delegates to share their experiences, research ideas and discuss various related issues and challenges. The event will provide an international technical forum for academicians, researchers, industry, organizational leaders, government and non-government representatives, management consultants and service providers to meet and exchange new ideas and present their findings of on-going research in various areas of industrial engineering.

The organizers have carefully selected four keynote lectures by experts from University and Industry along with over 240 technical papers by researchers in 37 parallel sessions. A slot is arranged for a panel discussion.

I am sure that the technical papers of the conference will provide a unique opportunity to rapidly disseminate research results that are of timely interest to the engineering fraternity. I warmly welcome all the participants and wish you all to have very fruitful technical sessions.

My hearty congratulations to the organizers of ICIE 2017 for organizing the event so well and convey my best wishes for the success of the conference.

Prof. S. R. Gandhi
Director

December 9, 2017

Head of Department's Message



I am happy to note that the Department of Mechanical Engineering of Sardar Vallabhbhai National Institute of Technology (SVNIT) Surat is organizing *4th International conference on Industrial Engineering (ICIE 2017)* in association with *Indian Institute of Industrial Engineering (IIIE), National Headquarters, Mumbai*, which is scheduled to be held during December 21-23, 2017.

Industrial Engineering is the one of important specialization of Mechanical Engineering. It deals with the design, improvement, and installation of integrated systems (as of people, materials, and energy) in industry. I suppose that the ICIE 2017 will bring academic, scientists, leading engineers, industry researchers and scholar students to exchange and share their experiences and research results about all aspects of Industrial Engineering, and discuss the practical challenges encountered and the solutions adopted.

The Department of Mechanical Engineering was established since the inception of college (1961). The department offers an undergraduate, five post graduate courses and Ph.D. programme in all the disciplines of Mechanical Engineering. The department has at present around 40 faculties and more than 1000 student. Apart from regular teaching, the department is actively engaged in testing, consultancy, and research and development services to support various industries in and around Surat.

I would like to welcome all the participants in Department of Mechanical Engineering. The departmental laboratories are open for visit during the working hours.

I give best wishes for the success of the conference.

December 09, 2017

Prof. K. P. Desai
Head of Department

IIIE Director General's Message



I am pleased to note that the Department of Mechanical Engineering of Sardar Vallabhbhai National Institute of Technology (SVNIT) Surat in collaboration with Indian Institution of industrial engineering Mumbai (IIIE) is organizing 4th International conference on Industrial Engineering (ICIE 2017), which is quite important and relevant theme for the Indian Industries and academia in global context.

Industrial engineering has evolved over the last century, constantly moving into new applications and industries using new tools—while never leaving its traditional industries. This Conference is aimed at discussing the emancipating dimensions of industrial engineering discipline, which has made progress during the last few decades. The industrial engineer (IE) has long concerned the profession because the term industrial may have been defined too narrowly. There may be other words starting with the letter

ICIE 2017 is a platform to bring researchers and experts from academia and industry on a common platform for discussing the latest technologies and managerial tools being adopted in the field of Science, Technology and Management. It will help to provide an opportunity for all branches of industries, to disseminate the information on most recent and relevant research, theories and practices in the area of Industrial Engineering.

I am sure that large number of distinguished speakers and delegates attending this conference would endeavor to deliberate on innovative ideas, contributing from their rich experience, in depth knowledge and success.

Organizing this type of conferences requires great amount of vision, leadership and dedication. I compliment SVNIT Surat and IIIE Mumbai for achieving this successfully.

My warm greetings to the distinguished speakers, delegates and all participants!

December 09, 2017

Dr. Bhaskar M. Bhandarkar
Chairman, IIIE

Message from the President IIIE Surat Chapter



I am greatly delighted that the Mechanical Engineering Department of SVNIT Surat in association with Indian Institution of Industrial Engineering (IIIE) has done marvellous work in organizing the ICIE-2017 scheduled during December 21-23, 2017.

Industrial engineering has evolved over the last century, constantly moving into new applications and industries using new tools—while never leaving its traditional industries. This Conference is aimed at discussing the emancipating dimensions of industrial engineering discipline, which has made progress during the last few decades. The industrial engineer (IE) has long concerned the profession because the term industrial may have been defined too narrowly. There may be other words starting with the letter

'I' that better capture the diversity of industrial engineering, including innovation, information, integration, implementation, instruction, involvement, and intrapreneur. Therefore, this Conference tries to expand the focus of the industrial engineering profession by recognizing that the *'I'* in IE may stand for many more things than the traditional term, *Industrial*.

I understand that around 250 papers will be presented in 37 technical sessions in this conference and delegates will be participating from various organizations. In summary, I can proclaim here that our industrial engineering professionals from academia, industry, government and service sector etc. have become responsive to the society's needs, have been adept at creating or advancing new technical tools and have advanced the knowledge frontiers of industrial and systems engineering discipline. I am having confidence that the participants of this conference will make productive efforts to transfer, disseminate and communicate the new and ever expanding dimensions of Industrial Engineering.

I congratulate specifically to Dr. Tushar N. Desai and Dr. Ravi Kant and many others for their continuous and sustained efforts in making the conference a successful one. I also convey my best wishes to the delegates, faculty members and other associates for their valued contributions to ICIE-2017.

Atik M. Desai

Chairman, IIIE Surat Chapter and
Vice President - Chief Administrative Officer
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Message from the President SVNIT Alumni Association – Surat Chapter



It is pleasure to note that Department of Mechanical Engineering is organizing 4th International Conference on Industrial Engineering (ICIE 2017) during 21st to 23rd December, 2017. We are delighted to be part of this prestigious technical event.

SVNIT ALUMNI ASSOCIATION – SURAT CHAPTER is the first registered chapter of the SVNIT ALUMNI ASSOCIATION. One of the main objectives of local alumni chapter is to promote and encourage sharing of technical information and knowledge for betterment of students and professional fraternity. Over last two years, the chapter has organized more than 20 events for alumni-students-faculty-staff of SVNIT. It includes technical seminars, cultural events, support/sponsorship of conference and other social events related to well being and life style, spirituality, yoga, blood donation, medical camp, etc. All these have been possible due to support of more than 225 local alumni members and faculty/staff of SVNIT.

I take this opportunity to thank distinguish alumnus Er. Bhadresh Shah, who is also the founder President of SVNIT ALUMNI ASSOCIATION for his contribution in supporting this noble cause. With his contribution to our local alumni chapter, this is the fourth technical conference that we are supporting/sponsoring for SVNIT. We shall further look forward to jointly support similar technical events for other departments in future.

I appreciate the efforts of Dr. Ravi Kant and Dr. Tushar N. Desai; organizing secretary of ICIE 2017 for their dedicated and sincere efforts in organizing this conference. I wish grand success to this technical event and hope that it will meet expectations of participants as well the organizers.

Nilesh Shah
President
SVNIT AA - SURAT CHAPTER

Message from the Conference Organizing Secretaries



Dr. Ravi Kant



Dr. Tushar N. Desai

The 4th International Conference on Industrial Engineering (ICIE 2017) is scheduled to be held during December 21-23, 2017. ICIE 2017 is a platform to bring researchers and experts from academia and industry on a common platform for discussing the latest technologies and managerial tools being adopted in the field of Science, Technology and Management. It will help to provide an opportunity for all branches of industries, to disseminate the information on most recent and relevant research, theories and practices in the area of Industrial Engineering.

There has been overwhelming response to the call for papers from the researchers, academicians of the leading institutes and organizations all over the world. The papers present theoretical research results and application case studies. Around 300 delegates will be attending the conference which consists of 4 keynote speeches and 37 Parallel Sessions. They range from mathematical modeling and simulation to industrial applications and management.

We would like to thank the reviewers and members of international advisory committee, faculty members of the department of mechanical engineering for their assistance and seriousness. We are very grateful to all authors and session chairs for contributing actively in this conference. We should acknowledge the student volunteers for their assistance.

We are extremely thankful to Larson and Toubro (L&T) Hazira, Surat, SVNIT Alumni Association, Surat Chapter and Swapn Preeti Bhadrash Shah Foundation, Surat, for extending their financial support to ICIE 2017. We are also thankful to 'Indian Institute of Industrial Engineering (IIIE)', National Headquarters, Mumbai for extending their valuable support to the conference.

We are extremely thankful to Dr. S. R. Gandhi, Director of our institute for their constant support and encouragement in making this international conference a success. We are also thankful to the Deans, Head of Departments, Hostel section and Estate section for various support required time to time.

We are also thankful to our Research Scholar Mr. Himanshu Prajapati, Ms. Shruti J. Raval, Ms. Umangi Pathak, Mr. Sachin Agarwal, Mr. Javed Malek, Mr. Pranay Parmar, Mr. Ashish Patel, Mr. Puneet Kumar and M. Tech. Students Mr. Sandeep Mani Tripathi, Mr. Mitesh Kumar Dabhi, Mr. Chintan Chaudhari, Mr. Venkatesh Burela and Mr. Mayank Soni for their efforts in bringing up this conference.

December 09, 2017

Dr. Ravi Kant and Dr. Tushar N. Desai
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SECTION – I
INDUSTRIAL ENGINEERING PRACTICES AND
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Suitability of TDABC for Small Scale Industries in India

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Abstract: Cost estimation is the need of the every industry. Time driven activity based costing (TDABC) has gained the lot of attention for accurate cost estimation. But, implementation of costing system requires investment in time and money. Further, small scale industries (SSI) have constrained on the uses of various resources such as time and money. Therefore, the aim of the paper is to understand the suitability of TDABC for SSI. This research examines suitability from the in-depth literature review and the survey. The study finds that, TDABC is suitable to SSI. But, future research is required by SSI. Because. Most of the studies were carried out in medium and large scale industries.

Keywords: TDABC, Time driven activity based costing, SSI, Review, Survey, Suitability

1. INTRODUCTION

In this Era of intense global competition on price and quality of products, there is a need of accurate cost information. The continual search for a better costing system ushered in the activity based costing (ABC). ABC was first designed for manufacturing processes (Wegmann, 2010). Using ABC can lead to classifying activities as value-added and non-value-added and allow for elimination of the non-value-added activities (Gunasekaran and Sarhadi, 1998). Therefore, ABC is a cost accounting system from the perspective of operational process. But, Kaplan and Anderson (2003) have suggested that many large organizations abandoned their ABC project because of rising cost and employee irritation. Then they proposed time driven activity based costing (TDABC) which is evolved from ABC. TDABC requires only two parameters i.e. unit cost of supplying capacity and time required to perform an activity (Demeere, Stouthuysen and Roodhooft, 2009). Time required to perform an activity is estimated using time equations.

The aim of the paper is to discuss the suitability of TDABC for small scale industry in India. The paper initially discusses the concept of TDABC followed by its evolution. Then the literature review of is discussed. Thereafter, the results of the survey are discussed. Finally, the suitability of TDABC is discussed for small scale manufacturing industry.

2. EVOLUTION OF TDABC

Earlier, in the eighties, traditional costing was used. In this system, indirect costs are distributed over product costs based on single or a few volume based cost drivers. While the direct cost is directly assigned to product cost.

Therefore, traditional costing system is suitable in stable environment with less or fixed indirect costs and with a small variation in activities, products or services (Cooper and Kaplan, 1988; Tse and Gong, 2009). But over a period, with the increasing manufacturing complexity, the traditional costing system was not able to produce accurate costing. Therefore, to determine accurate and reliable costing and to provide managerial reports ABC was developed.

According to Hilton (2005), “ABC is a two stage procedure used to assign the overhead cost to products and services produced”. In the first stage, activity cost is determined. In the second stage, product cost is determined by allocating activity cost based on the product’s consumption. But, because of employee irritation and high maintenance cost, many industries abandoned their ABC model (Kaplan and Anderson, 2003). So, a new simpler TDABC approach is developed, which is based on existing ABC model.

TDABC model simplifies ABC by elimination difficulties in implementation. It reduces the work of interviewing and polling staff to assign resources to activities. This model assigns resources cost directly to the products. TDABC requires only two sets of estimations. First, it calculates the cost of supplying resource capacity. Second, it calculates capacity rate.

3. CONCEPT OF TDABC

Kaplan and Anderson (2003) have introduced TDABC to overcome difficulties in traditional ABC. This method identifies the capacity of each department or process and allocates the cost of this capacity of resource groups over the cost object based on the time required to perform an activity (de Arbuló et al., 2012). Like ABC, TDABC is also

a two step process as shown in Fig. 1; in first step overhead cost is assigned to activity and in second step activity cost is assigned to product or service. In this process TDABC requires only two parameters. First parameter is unit cost of supplying capacity. Where unit cost is calculated using equation 1

$$\text{Unit cost} = \frac{\text{Cost of capacity supplied}}{\text{Practical capacity of resources supplied}} \quad (1)$$

Second parameter is consumption of capacity (unit times) by the activities the organization performs for products, services, and customers. The consumption of capacity by an activity is generally measured in terms of time. It is calculated by an equation 2, which is also called as time equation. A time equation is an equation that describes the time to perform an activity as a function of several drivers.

$$\text{Time required each time the activity} = \beta_0 + \sum \beta_i \cdot X_i \quad (2)$$

Where

β_0 is the standard time to perform the basic activity,
 β_i is the time for each incremental activity,
 X_i is the quantity of each incremental activity

Demeere, Stouthuysen and Roodhooft (2009) and Stouthuysen et al. (2010) have given the following steps for implementing TDABC. The complete process is shown in Fig. 1

- Identify the various activities (resource groups, departments)
- Estimate the total cost of each activities
- Estimate the practical capacity of each resource group
- Calculate the unit cost of each activity
- Determine the time required each time the activity is performed
- Multiply the unit cost of each activity by the time estimate for the event.

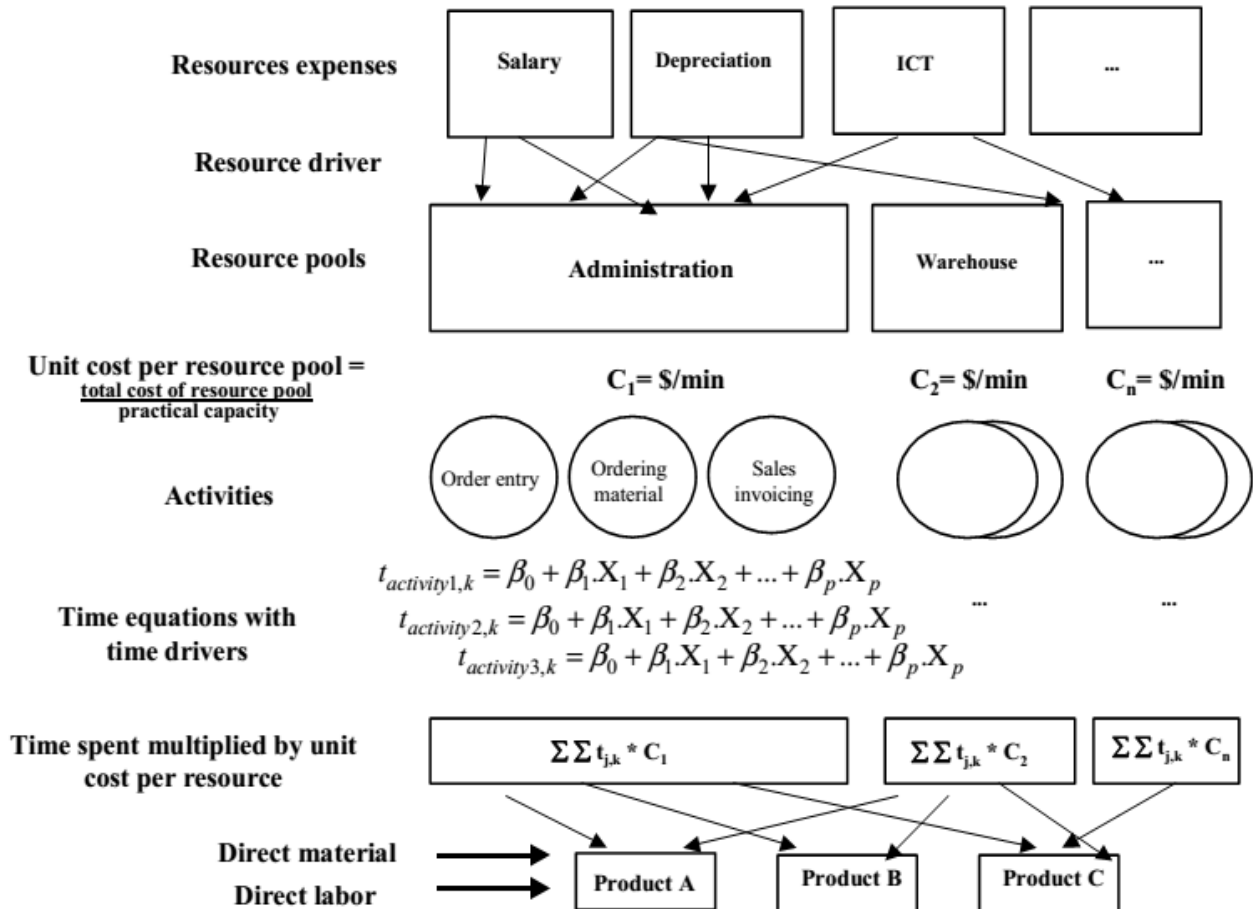


Fig. 1. TDABC Schematic (Everaert et al., 2008)

4. REVIEW OF TDABC

Many researchers conducted the case studies of TDABC implementation at different industries. These case studies are related to pig production, casting manufacturing,

electronic product manufacturing, wooden toys manufacturing, bicycle manufacturing, auto part manufacturing and precision casting factory. All these companies are medium or large scale in nature. The detail of these case studies is presented in

TABLE .

TABLE 1: Case studies on TDABC

Author	Type of industry	Remarks
(Bryon et al., 2008)	pig production	- TDABC can be used for guiding management with the decision problem of switching to batch farrowing in pig production - TDABC is useful to quantify both the economic and ecological impacts of a strategic decision
(Öker and Adigüzel, 2010)	casting manufacturing company	- TDABC model is more appropriate and easier for service companies to implement than manufacturing companies. - TDABC provides more relevant information about capacity utilization than standard costing and product profitability - Difficult to implement TDABC in manufacturing companies because the capacities are measured in terms of labor time, and some time it is difficult to measure capacity in terms of labor time
(Stout and Propri, 2011)	electronics company	Updating TDABC model is easier than ABC
(de Arbulo et al., 2012)	auto parts manufacturer	- TDABC is easier to use than ABC and traditional full costing in multiproduct/multi-process companies. - TDABC can capture the cost of the different products in the product mix. - TDABC calculates the cost of a product accurately, whereas Value Stream Costing (VSC) gives just an average value. But data collection for TDABC is complex
(Kachitvichyanukul, Luong and Pitakaso, 2012)	precision casting factory	The results of TDABC provide valuable information to managers for reducing waste in their business endeavors
(Monroy, Nasiri and Peláez, 2014)		- TDABC covers both product and process levels for decision making. - TDABC is not adapted to Generally Accepted Accounting Principles (GAAP) and companies that are using these systems should have another system generating reports for external uses
(Pongwasit And Chompu-Inwai, 2016)	manufactures wooden toys	- TDABC is more accurate and determine the appropriate prices of the products. - They found that TDABC identifies the production cost was consistent with the actual use of resources at the study company
(Siguenza Guzman et al., 2013)	.	Difficult to measure the time, the homogeneity and its maintenance
(Chiarini, 2014)		Difficult to implement because of time equations
(Kowsari, 2013)		If time is measured by inexperienced person, and if wrong time is considered for an activity then cost price allocated to activities will be unreliable

The researches have opined that TDABC provides more relevant information for capacity utilization, is used for quantifying economical and ecological impact, can capture the cost of different products in product mix, and is more easier than traditional costing more particularly ABC. But, most of the problems are related with the time estimation and formulation of time equation.

4.1 Advantages of TDABC

From the evaluation of TDABC system, many industries have implemented TDABC. Benefits of TDABC mentioned by different authors in manufacturing sector are given in TABLE

TABLE 2: Advantages of TDABC

Reference	Conclusion
(Bryon et al., 2008)	1) Guide managers with the decision problem 2) Allow to derive trade-offs between economic and ecological criteria
(Korpinen, Mochan and Uusitalo, 2010)	1) Assist management in strategic decision making 2) Enable a sensitivity analysis of production 3) Accurate, applicable and effective model
(Öker and Adigüzel, 2010)	1) It provides more relevant information about capacity utilization than standard costing and product profitability
(Stout and Propri, 2011)	1) Updation in the model more easier than in ABC. 2) TDABC is implemented with the support of ERP
(de Arbulo et al., 2012)	1) Capture the costs of the different products in the product mix 2) Analyze how capacity is being used
(Monroy, Nasiri and Peláez, 2014)	1) TD-ABC covers both product and process levels for decision making
(Mortaji, Bagherpour and Mazdeh, 2013)	1) TDABC is quick and easy costing method for determining the “Whale curve” of customer profitability and a natural complement to the balanced scorecard
(Pongwasit and Chompu-Inwai, 2016)	1) costing is more consistent with the actual use of resources
(Wouters and Stecher, 2017)	1) TDABC avoids grouping resources into cost pools, and so it has far fewer linkages that need to be updated 2) TDABC is flexible system.

Above discussion indicates that TDABC is a useful tool for managers and decision makers because it provides detailed and hierarchical decomposition of the cost.

4.2 Limitations of TDABC

Like every system TDABC is also having some limitations as given in TABLE

TABLE 3: Limitations of TDABC

Reference	Limitation
(Wegmann and Nozile, 2008)	1) TDABC is only useful for standard processes such as chain management supplying, some standardized production processes and consulting activities, call centers, hospitals, etc.
(Sherratt, 2005)	1) TDABC is limited to predetermined routines and activities
(Gervais, Levant and Ducrocq, 2010)	1) If staff reports their times when it is not possible to observe them directly then accuracy is debatable
(de Arbulo et al., 2012)	1) Collect data for TDABC seems to be complex
(Siguenza Guzman et al., 2013)	1) Over time it is difficult to measure the time, the homogeneity and its maintenance. 2) Estimating time for non-continuous or unpredictable activities is difficult

Reference	Limitation
(Mortaji, Bagherpour and Mazdeh, 2013)	1) Deviation in practical capacity and the required time for each activity may mislead managers into making inappropriate decisions
(Chiarini, 2014)	1) The drawback of the use of time equations is a deep and difficult analysis of all the activities and their internal transactions 2) Practical capacity is not that easy to calculate; often it is an approximation. However, at the same time, practical capacity needs to be accurate

The above limitations indicate the scope for improvement and area for further research. They are as follows.

- A continuous improving system can be developed so that cost for non routine activities can be determined.
- Instead of dependent on employees for data, continuous data recording system can be developed. Such continuous recording system will also solve the problem of estimating time for unproductive activities and it help to measure practical capacity.
- A methodology can be developed to simplify time equations and their analysis.

5. SURVEY

A survey on product costing was carried out by the authors to study the current practices in product costing in context of small scale furniture manufacturing industries in India. The aim of the survey was to determine:

- Which Costing method is used in the industry?
- What are the important aspects in costing process?
- How overhead are distributed over the product.
- What is the data recording system?

The survey was carried out in 25 industries. Industries having turnover less than 3 crore were selected for survey. A questioner was prepared (Appendix A) and personal interview was carried out.

5.1 Survey findings

When asked about costing technique used in their industry, none of them were able to answer. But during the discussion it was found that most of them were using traditional costing system, where as a few of them were using feature based costing system. The graphical representation of companies using different costing system is as shown in Fig. 2

To understand the importance of aspects of costing for the industries, The preference of aspects of costing process was asked. The result is shown in TABLE . It indicates that, small scale industries need fast and easy accurate system, which will be affordable to them. During the fourth and fifth question it is observed that, the overhead like water

consumption were neglected, whereas other overheads were added as percentage. The percentage of distribution was determined from the past experiences or in the proportion of last year. Some of the companies were electric cost as 2% to 3% of basic cost of product.

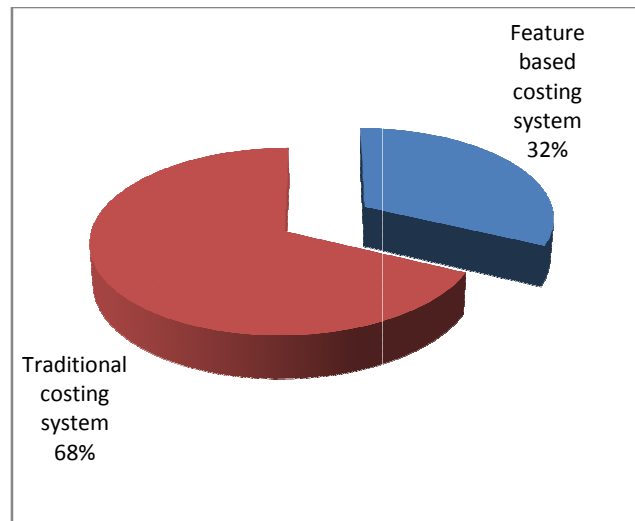


Fig. 2. Costing system used in small scale manufacturing industry

TABLE 4: Preference of aspects of costing process

Sr. No	Aspects of costing process	Preference
1	Accuracy of the estimate	1
2	Time taken to estimate & cost involved in costing process	2
3	Understanding of manufacturing process	3
4	Dependency of market data like material cost, operation rate	4
5	Complexity of calculations	5

When asked about the data collection system, it is observed that, 22% of the industries were having system or tool for data recording, which were in the organized sector, while remaining 78% were belongs to unorganized sector. It is represented graphically in the Fig. 3.

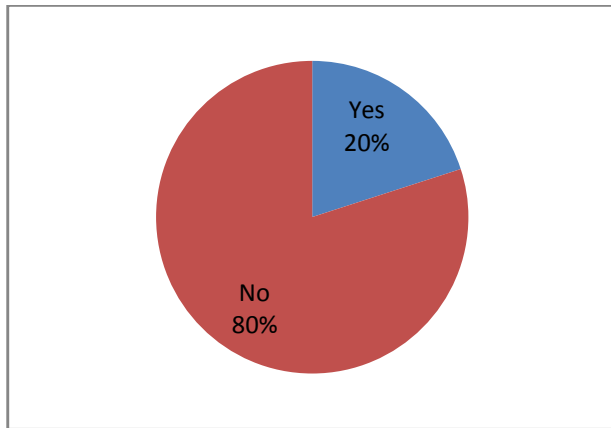


Fig. 3. Data recording system in industry

6. PROBLEMS IN SSI

In most of the countries, small scale industries (SSIs) are defined in terms of number of employees whereas in India, they are defined in terms of investment in plant and machinery (Singh, Garg and Deshmukh, 2010). In India, SSIs are defined as industries having investment in plant and machinery (excluding land & buildings) less than Rs 5 crore. Therefore costing system with low investment cost is a need of SSIs in India. Apart from this, in SSI, there are less employees. Therefore, one employee is handling many activities. Therefore, the capacity utilization of the machines and the activity is less. Hence, it is difficult to measure the practical capacity of the activity.

7. RESULTS AND DISCUSSIONS

The authors have conducted a survey at small scale manufacturing industries to understand, how cost estimation is carried out in industry. The cost estimators agreed on this during the interviews that, different cost estimators making similar estimates have different results because of the choice of the resource and method. Further discussion with cost estimators have indicated that, small scale industries in India don't have system to measure resources consumed in manufacturing. Based on this, following are the requirements of cost estimation technique for SSIs:-

7.1 Requirements of cost estimation techniques for SSI

Based on the literature and survey conducted by author following requirements of cost estimation techniques for small scale manufacturing industries are identified.

- A costing system should predict accurate cost of product.
- It should distribution of overheads should be in accordance with the way the resources are consumed.
- It should be able to measure unused capacities.

- It should determine the cost of each process or activity.
- Cost of small consumables like water should be considered in costing.
- Rejection cost of a product should be considered on the same product.
- Inefficient process and employee should be determined.
- Cost consuming activities should be identified.

7.2 Suitability of TDABC for Cost Estimation for SSI

From the literature discussed above, following features of TDABC makes it suitable for small scale manufacturing industry:-

- Provides the most accurate cost estimates
- Provides detailed cost structure
- Distributes the overhead in accordance with the way the resources are consumed
- Measures the unused capacities
- Determines the cost of each activity
- Easy to implement and easy to maintain
- Less cost of implementation
- Less data is required for cost estimation

8. CONCLUSION

Many researchers have attempted to implement TDABC in manufacturing industry. They pointed out the advantages and limitations in their respective studies. However, the aim of this paper was to understand the suitability of TDABC for SSI in India. Therefore, the detailed review of TDABC was carried out. Then the survey was conducted to study need of SSI were studied. The results and the discussion of the survey indicate that, TDABC is suitable to SSI in India. But, it was found that, most of the studies were written by creators of TDABC. Further it is observed that most of the studies were in medium or large scale industries. Hence future research is required by in manufacturing industries and especially in small scale industries.

Also, Organizations prefer to take actions to reduce the effects of the drivers instead of using them to allocate indirect cost. Hence the visibility to process efficiencies and capacity utilization is more important to them. Therefore, TDABC is more suitable to manufacturing industries.

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APPENDIX A

- i. Name & Designation or Role : _____
- ii. Phone no : _____
- iii. Email Address : _____
- iv. Name of Organization : _____
- v. Do you use any costing technique / Method? Yes/ No
- vi. Describe the current cost estimation process followed in your organization

- vii. What are the different challenges you have faced during current costing process?

- viii. How you are recording data for costing?

- ix. Do you have any cost measurement and control system? If yes then specify.

- x. Do you use any tool/software for cost measurement and control? If yes then specify.

- xi. Do you have any system like SAP or ERP?If yes then specify.

- xii. At what stages of production cost estimation is worked out?
1) Concept 2) Design 3) Prototype 4) Sourcing 5)Production6) Dispatch
- xiii. Following aspects of costing process matters me most
 - 1) Time taken to estimate & cost involved in costing process
 - 2) Accuracy of the estimate
 - 3) Complexity of calculations
 - 4) Dependency of market data like material cost, operation rate
 - 5) Understanding of manufacturing process
- xiv. How expenses like water, electric are added to the cost?

- xv. How indirect expenses like marketing, depreciation, maintenance are added to the cost?

The Effect of Demographic Variables on Attitude towards Risk with Respect to Financial Investment Decision

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Abstract:

Purpose – This paper aims to investigate the effect of demographic variables on attitude towards risk with respect to financial investment decision. The association between demographic variables and risk appetite for financial investment decision are also examined.

Design/Methodology/Approach – The structured questionnaire survey using multi-stage sampling method was conducted. The approximate sample size has targeted 735 investors of Surat City, India.

Findings – Ethnic groups do have significant impact on various aspects of financial investment decision. It has been also observed from the study that there is a significant association between ethnic groups and various aspects of financial investment decision such as awareness level towards financial avenues, types of portfolio, objectives for investment, risk associated with financial avenues and preference given to financial avenues for investment.

Originality/ Value – This research article will deliver the information about effect of investor's demographic characteristics. The article provides the scope for further hypothesis testing, development of new theories focusing relationship between demographic variables and risk appetite and its impact on financial investment demeanor. It will also be helpful to the researchers for further research in the area of consumer behavior for financial investment decision.

Keywords: consumer behavior, risk appetite, financial investment, ethnic groups

1. INTRODUCTION

Consumer behavior has always fascinated marketers all over the world. Rightly so, because it offers interesting insights into the working of the human mind in making purchasing decisions. The study of consumer behavior is a subjective topic. Hence, there are no absolutes. It was also found that the investor behavior is the process by which investor tends to satisfy his/her needs by showing their choices. The behavior of the investor can be affected by many of internal as well as external environment. The demographical factors play critical role in determining individual buying behavior for any goods or even services. Various studies have been conducted to identify investor buying behavior to identify how Investors are making financial planning to satisfy their future financial need. The income earning and income spending activities are a part of financial system (Prasad & Srinivas, 2012). It channelizes the savings of millions of small and retail investors into gigantic capital formation. Today, investors have large number of options available for investment i.e. Stock market, Bank F.D., Insurance (ULIPS), Mutual funds, PPF,

NSC, KVP, Real estate, Small medium enterprise, Agricultural product, Cottage industry, Bonds, Gold etc. All these financial instruments mobilize financial resources in the economy (Senthilkumar, Vijayabanu, & Nayagam, 2008).

Risk is an inherent feature of all types of financial investments due to the variability in the actual and expected returns on investment. The concept 'risk perception' means the way in which investors view the risk of financial assets, based on their concerns and experience. The attitude towards risk of investors is an important factor that influences the investment decisions. The risk-taking attitude determines the investment style (Bali et al., 2009; Fellner and Maciejovsky, 2007; Hunter and Kemp, 2004). An investor's psychology is one of the important factors that affect their perception about the market and attitude toward risk (Chang, 2008; Kourtidis et al., 2011; Young et al., 2012). Based on individual risk tolerance level, investors are classified into three categories: risk-averse, risk-neutral and risk-lovers. Demographic factors that have a significant impact on the investors' attitude towards risk include age,

gender, marital status, qualification, occupation, ethnic group, family type and level of income. Investors take risks according to their interpretation and perception which ultimately affect their behavior towards risky investment decisions.

Surat is India's 8th and Gujarat's 2nd largest city with the population of 4.5 million. Surat is also ranked 4th fastest growing cities in the Asia per capital. Among the highest income growing tax payer city in Asia in the year 2010-11 Surat contributed at 2200 crores to national exchequer. Surat is city with highest average annual household income. Surat is a standout. Surat has nearly the population size of a megacity; it is the youngest city in the entire group (with over 64% of the population below the age of 30); and the city's household income growth tops our urban universe by a comfortable margin. After adjusting for cost of living differences, Surat emerges as the leader in household income levels. The city is already a larger consumer market than Ahmedabad and Pune. The well developed commercial city of Gujarat, Surat has contributed a GDP of \$40 billion. The city is popularly known as the diamond capital of the world and the textile capital of India. In 2008, Surat was dubbed the wealthiest city of India in terms of per-capita income — at approximately equal to INR 4,57,671 according to a study jointly conducted by the National Council of Applied Economic Research's Rajesh Shukla and Future Capital Research's Roopa Purushothaman. Besides textile manufacturing, trade, diamond cutting and polishing industries, the city is also supported by intricate Zari works, chemical industries and the petrochemical and natural gas-based industries at Hazira, established by leading industry houses like Oil and Natural Gas Company Limited, Reliance Industries Limited, Essar Limited and Shell Limited (www.thesuniljain.com).

This research will take into account the effect of demographic variables on attitude towards risk with respect to financial investment decision. According to literature survey, individual's demographic characteristics have been proved to play a vital role in determine their risk taking attitude and in achieving financial goals. It has been stated that the demographic variables of investors and attitude towards risk are fully integrated into the consumer financial behavior. This research will support the belief that the influence of demographic variables on attitude towards risk regarding financial investment should not be ignored.

2. LITERATURE REVIEW

Park and Mahmood (2015) studied the impact of personality on risk tolerance and investment decisions. The purpose of the study was to investigate the relationship between risk-taking attitude, personality trait and investment decision among potential private investors in Kazakhstan, a post Soviet transition country. The authors

have adopted the quantitative research method. They have conducted the survey of students and teachers from a business school of Kazakhstan. The findings revealed that some of the personality traits has a significant positive effect whereas few have negative effect as well on the level of risk tolerance. The level of risk averse was differing with respect to gender and past investment experience. They also have found that level of risk tolerance have significant association with intention to invest in stock market. Based on the results they have suggested that investment advisor or agents should consider the personality trait and risk tolerance capacity while giving advice to private investors. (Park O. and Mahmood M., 2015)

Sindhu and Rajitha Kumar (2014) have studied the influence of risk perception of investors on investment decision. Their aim of research was to find the influence of risk perception on individual investors' investment decision particularly for mutual fund. The convenience sampling method were used to collect the response from investors of Kerala with used of structured questionnaire. The collected data were analyzed using various statistical tools like standard deviation, co-efficient of variance and simple regression analysis with the help of SPSS. Based on the analysis, the authors have concluded that investment decisions are very much influenced by investors' risk perception. Types of portfolio selection for financial investment have greater impact on risk perception. The investor preferred diversified portfolio than conservative portfolio to reduce the risk. They also have observed from the mean score analysis regarding risk perception of investors' that higher rate of return, the greater is its associated risk. (Sindhu K. P. and Rajitha Kumar S., 2014)

Shafi (2014) has studied the determinants influencing individual investor behavior in stock market. The aim of the author was to review the reported work to get the information and knowledge related to factors influencing investment behavior in different countries and their impact on risk tolerance and investment decision making process between men and women and among different age groups. The author has collected the various papers on determinants of investment behavior across the various different countries and prepared review paper. Thus, the researcher has adopted an exploratory study as a methodology. The conclusion revealed that there are number of elements which influence the individual investment behavior in stock market. It has been also found that some factors have enormous impact and other have little role to play in influencing individual investment behavior. The factors influencing individual investment behavior have been grouped into demographic, economic, social, psychological and uncommon in nature. The factors having a significant impact on individual investment behavior are age, gender, marital status, and confidence, irrational thinking, education, cognitive bias, past performance of the company,

risk factors, dividends, ownership structure, expected corporate earnings, accounting information and bonus payments. The uncommon factors found in various literature surveys conducted for different countries includes perceived ethics of the firm, stock marketability, publicity, inflation, expected losses in international financial markets, trading opportunity, diversification purpose, brand perception, control orientation, economic expectation and social responsibility which also have significant influence on individual investment decision.(Shafi, 2014)

Strydom and Metherell (2012) have conducted the research to find how demographic factors affect financial risk tolerance in a South African context. Stratified random sample was selected and binary logistic model was used to analyse the collected data to analyse the effect of independent demographic variables on financial risk tolerance level. Based on the analysis on the analysis, it was found that demographic characteristics of individuals play a significant role in establishing the level of risk tolerance. The major impact in determine the level of risk tolerance were played by age, income and gender. Whereas race and religion were not having significant influence on individual's subjective risk tolerance level. The authors also have observed that education did not affect level of risk tolerance significantly which is controversial to the various international evidence. It was also suggested based on results that marital status did not have much influence in establishing the individual's level of risk tolerance. (Strydom B. and Metherell C., 2012)

Anbar and Ekbar (2010) have conducted a study to investigate the relationship between different variables of financial risk tolerance and demographic characteristics. For analysis of data from 1100 university students, logistic regression, t-test and ANOVA analysis were sued. The analysis indicated that gender, department, working in job, monthly personal income, monthly family's total income and total net asset have significance in differentiating individuals into risk tolerance levels. But age, marital status and number of children have no significant effect on financial risk tolerance. The financial risk tolerance level of male students was higher than the female students. T-test have showed the result that financial risk tolerance level of student who are working in job were higher than non-working students. It has been also observed that there was a significant difference in risk tolerance level with respect to total monthly family's income and total net asset. Higher the family's total income, financial risk tolerance level were higher. Furthermore, lowest total net asset, the financial risk tolerance level was low. The results of the analysis supported the proposition about being effect of demographic variables on financial risk tolerance level.

Sung and Hanna (1997) have studied the factors related to risk tolerance. Their purpose of the study was to investigate the effects of individual characteristics and financial

variable on risk tolerance. They have chosen the 1992 Survey of Consumer Finances as their data set. Logistic regression analysis method was used to analysis their data set. They have found that difference in risk tolerance by gender, ethnic group, marital status and education could be due to difference in understanding regarding nature of risk. The result have shown that those who were more away from retirement have high risk tolerance than similar respondent whose expected retirement was closer. Ethnic group or race has significant influence on risk tolerance. The finding suggested that Non-Hispanic Whites had higher risk tolerance than Hispanic or those in other ethnic group than Blacks. Non-Hispanic Blacks had the lowest risk tolerance level. The authors also have observed that increased in predicted risk tolerance level with the increased in education level whereas, there were no significant difference noted among different occupations towards risk tolerance level. It was observed that there was significant impact of marital status and gender on risk tolerance level. The result showed those female headed households were lower risk tolerance level than male headed or married couples. (Sung J. and Hanna S., 1997)

3. RESEARCH METHODOLOGY

This study is exploratory and descriptive and is undertaken to understand the investors' behavior in the Surat city, India. The data has been collected from the homogenous sample that is the investors of Surat city, India. But again there has been heterogeneity among the investors as they fall into different ethnic groups. Data have been collected from various respondents through a structured questionnaire. Questionnaire contains rating scales and multiple choice questions. The target respondents have been requested to indicate their preference using a five scale likert scale. A sample survey has been conducted to estimate the population attributes by using a multi-stage sampling method using purposive sampling, convenient sampling and snowball sampling. The approximate sample size has been targeted 735 investors of Surat City, India.

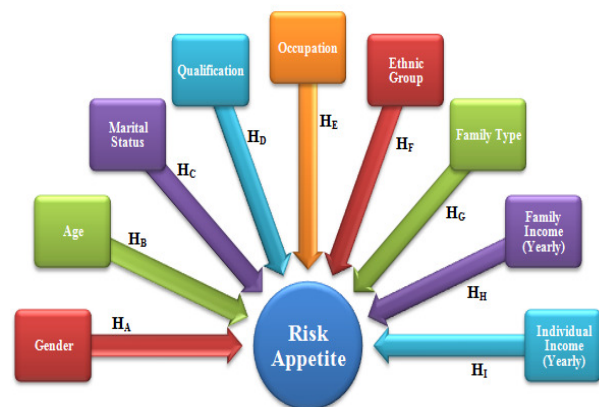


Fig. 1. Conceptual framework of hypothesis

4. RESULT AND DISCUSSION

The data in this study were coded and tabulated. The data were analyzed with the help of SPSS package (IBM SPSS Statistics v22.0) which enabled data interpretation and making of statistical inferences.

Hypothesis –

H₀: The demographic variables of investors do not have an impact on risk appetite for financial investment decision.

H₁: The demographic variables of investors do have an impact on risk appetite for financial investment decision.

Profile of Investors –

Table 1 shows the demographic profile of investors.

TABLE 1: Profile of investors

Variables		No. of investors	Percentage
Gender	Male	550	74.8
	Female	185	25.2
	Total	735	100
Age	18-24	90	12.2
	25-34	182	24.8
	35-44	170	23.1
	45-54	160	21.8
	55-64	87	11.8
	65 & above	46	6.3
	Total	735	100
Marital Status	Single	132	18
	Married	582	79.2
	Divorced	5	0.7
	Widowed	12	1.6
	Separated	4	0.5
	Total	735	100
Qualification	Under Graduate	134	18.2
	Graduate	355	48.3
	Post Graduate	181	24.6
	Professional	42	5.7
	Others	23	3.1
	Total	735	100
Occupation	Student	26	3.5
	Service	408	55.5
	Business	127	17.3
	Professional	98	13.3
	Retired	62	8.4
	Housewif	14	1.9

Variables		No. of investors	Percentage
	e		
	Total	735	100
Ethnic Group	Ethnic Group A	521	70.9
	Ethnic Group B	106	14.4
	Ethnic Group C	98	13.3
	Ethnic Group D	10	1.4
	Total	735	100
Family Type	Joint	399	54.3
	Nuclear	265	36.1
	Extended	71	9.7
	Total	735	100
Family Income	<200000	92	12.5
	200001-350000	129	17.6
	350001-500000	185	25.2
	500001-650000	102	13.9
	650001-800000	75	10.2
	More than 800000	152	20.7
	Total	735	100
Individual Income	<50000	107	14.6
	50001-100000	79	10.7
	100001-200000	134	18.2
	200001-300000	136	18.5
	300001-400000	88	12
	More than 400000	191	26
	Total	735	100

H_A- Gender and Risk Appetite for Financial Investment Decision

In order to know the association between gender and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among gender towards risk appetite, the Mann-Whitney U test has been performed. For this purpose, the following null (H₀) hypothesis and alternative (H_A) hypothesis have been proposed.

H₀: There is no significant association between gender and risk appetite for financial investment decision.

H_A: There is a significant association between gender and risk appetite for financial investment decision.

Based on analysis performed with the help of SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 38.207. The p values of these investment avenues at 5% significant level 0.000. As the calculated value of p is less than the critical value, so we could reject null hypothesis and conclude that there is a significant association between gender and risk appetite for financial investment decision.

H₀: There is no significant difference among gender towards risk appetite for financial investment decision

H_A: There is a significant difference among gender towards risk appetite for financial investment decision.

From the analysis performed with the help of SPSS, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.000. As p value is less than the critical value, so we reject null hypothesis, which means there is a significant difference among gender towards risk appetite for financial investment decision.

H_B- Age Groups and Risk Appetite for Financial Investment Decision

In order to know the association between age groups and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among age groups towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the following null (H₀) hypothesis and alternative (H_A) hypothesis have been proposed.

H₀: There is no significant association between age groups and risk appetite for financial investment decision.

H_A: There is a significant association between age groups and risk appetite for financial investment decision.

Based on the analysis performed, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 20.046. The p values of these investment avenues at 5% significant level 0.029. As the calculated value of p is less than the critical value, so we could reject null hypothesis and conclude that there is a significant association between age groups and risk appetite for financial investment decision.

H₀: There is no significant difference among age groups towards risk appetite for financial investment decision

H_A: There is a significant difference among age groups towards risk appetite for financial investment decision.

Based on the values found in the test, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.014. As p value is less than the critical value, so we reject null hypothesis, which means there is a significant difference among age groups towards risk appetite for financial investment decision.

H_C - Marital Status and Risk Appetite for Financial Investment Decision

In order to know the association between marital status and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among marital status towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the following null (H₀) hypothesis and alternative (H_A) hypothesis have been proposed.

H₀: There is no significant association between marital status and risk appetite for financial investment decision.

H_A: There is a significant association between marital status and risk appetite for financial investment decision.

From the various test performed using SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 9.494. The p values of these investment avenues at 5% significant level 0.302. As the calculated value of p is more than the critical value, so we fail to reject null hypothesis and conclude that there is no significant association between marital status and risk appetite for financial investment decision.

H₀: There is no significant difference among marital status towards risk appetite for financial investment decision

H_A: There is a significant difference among marital status towards risk appetite for financial investment decision.

Based on the Analysis, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.395. As p value is more than the critical value, so we fail to reject null hypothesis, which means there is no significant difference among marital status towards risk appetite for financial investment decision.

H_D - Qualification and Risk Appetite for Financial Investment Decision

In order to know the association between qualification and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among qualification towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the

following null (H_0) hypothesis and alternative (H_A) hypothesis have been proposed.

H_0 : There is no significant association between qualification and risk appetite for financial investment decision.

H_A : There is a significant association between qualification and risk appetite for financial investment decision.

Based on the analysis performed using SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 18.935. The p values of these investment avenues at 5% significant level 0.015. As the calculated value of p is less than the critical value, so we could reject null hypothesis and conclude that there is a significant association between qualification and risk appetite for financial investment decision.

H_0 : There is no significant difference among qualification towards risk appetite for financial investment decision

H_A : There is a significant difference among qualification towards risk appetite for financial investment decision.

Based on the value found from the test, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.039. As p value is less than the critical value, so we reject null hypothesis, which means there is a significant difference among qualification towards risk appetite for financial investment decision.

H_E - Occupation and Risk Appetite for Financial Investment Decision

In order to know the association between occupation and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among occupation towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the following null (H_0) hypothesis and alternative (H_A) hypothesis have been proposed.

H_0 : There is no significant association between occupation and risk appetite for financial investment decision.

H_A : There is a significant association between occupation and risk appetite for financial investment decision.

From the value found in Pearson Chi-square test, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 28.617. The p values of these investment avenues at 5% significant level 0.001. As the calculated value of p is less than the critical value, so we could reject null hypothesis and conclude that there is a significant association between occupation and risk appetite for financial investment decision.

H_0 : There is no significant difference among occupation towards risk appetite for financial investment decision

H_A : There is a significant difference among occupation towards risk appetite for financial investment decision.

As per analysis run through SPSS, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.000. As p value is less than the critical value, so we reject null hypothesis, which means there is a significant difference among occupation towards risk appetite for financial investment decision.

H_F - Ethnic Group and Risk Appetite for Financial Investment Decision

In order to know the association between ethnic groups and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among ethnic groups towards risk appetite, the Kruskal Wallis test has been performed. To examine the weighted mean for each risk taking level for financial investment decision, the mean score analysis has been calculated. For this purpose, the following null (H_0) hypothesis and alternative (H_A) hypothesis have been proposed.

H_0 : There is no significant association between ethnic groups and risk appetite for financial investment decision.

H_A : There is a significant association between ethnic groups and risk appetite for financial investment decision.

Based on the analysis run using SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 9.009. The p values of these investment avenues at 5% significant level 0.173. As the calculated value of p is more than the critical value, so we could fail to reject null hypothesis and conclude that there is no significant association between ethnic groups and risk appetite for financial investment decision.

H_0 : There is no significant difference among ethnic groups towards risk appetite for financial investment decision

H_A : There is a significant difference among ethnic groups towards risk appetite for financial investment decision.

As per analysis run through SPSS, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.203. As p value is more than the critical value, so we fail to reject null hypothesis, which means there is no significant difference among different ethnic groups towards risk appetite for financial investment decision.

H_G - Family Type and Risk Appetite for Financial Investment Decision

In order to know the association between family type and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among family type towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the following null (H_0) hypothesis and alternative (H_A) hypothesis have been proposed.

H_0 : There is no significant association between family type and risk appetite for financial investment decision.

H_A : There is a significant association between family type and risk appetite for financial investment decision.

Based on the analysis using SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 4.674. The p values of these investment avenues at 5% significant level 0.322. As the calculated value of p is more than the critical value, so we could fail to reject null hypothesis and conclude that there is no significant association between family type and risk appetite for financial investment decision.

H_0 : There is no significant difference among family type towards risk appetite for financial investment decision

H_A : There is a significant difference among family type towards risk appetite for financial investment decision.

From the various test run using SPSS, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.429. As p value is more than the critical value, so we fail to reject null hypothesis, which means there is no significant difference among family type towards risk appetite for financial investment decision.

H_H - Family Income (Yearly) and Risk Appetite for Financial Investment Decision

In order to know the association between family income (yearly) and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among family income (yearly) towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the following null (H_0) hypothesis and alternative (H_A) hypothesis have been proposed.

H_0 : There is no significant association between family income and risk appetite for financial investment decision.

H_A : There is a significant association between family income and risk appetite for financial investment decision.

Based on the Pearson Chi-square test performed using SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is

32.383. The p values of these investment avenues at 5% significant level 0.000. As the calculated value of p is less than the critical value, so we could reject null hypothesis and conclude that there is a significant association between family income and risk appetite for financial investment decision.

H_0 : There is no significant difference among family income towards risk appetite for financial investment decision

H_A : There is a significant difference among family income towards risk appetite for financial investment decision.

Based on the values found in the test, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.007. As p value is less than the critical value, so we reject null hypothesis, which means there is a significant difference among family income towards risk appetite for financial investment decision.

H_I - Individual Income (Yearly) and Risk Appetite for Financial Investment Decision

In order to know the association between Individual income (yearly) and risk appetite for financial investment decision, the Pearson's chi-square test at 5% significant level has been carried out. Furthermore, to investigate the difference among individual income (yearly) towards risk appetite, the Kruskal Wallis test has been performed. For this purpose, the following null (H_0) hypothesis and alternative (H_A) hypothesis have been proposed.

H_0 : There is no significant association between individual income and risk appetite for financial investment decision.

H_A : There is a significant association between individual income and risk appetite for financial investment decision.

Based on analysis performed with the help of SPSS, it is observed that calculated value of chi-square for risk appetite regarding financial investment decision is 22.323. The p values of these investment avenues at 5% significant level 0.014. As the calculated value of p is less than the critical value, so we could null hypothesis and conclude that there is a significant association between individual income and risk appetite for financial investment decision.

H_0 : There is no significant difference among individual income towards risk appetite for financial investment decision

H_A : There is a significant difference among individual income towards risk appetite for financial investment decision.

Based on analysis performed with the help of SPSS, the p value of population median at 5% significant level of risk appetite for financial investment decision is 0.026. As p

value is less than the critical value, so we reject null hypothesis, which means there is a significant difference among individual income towards risk appetite for financial investment decision.

5. CONCLUSION

The purpose of this study was to investigate the effect of demographic variables on attitude towards risk with respect to financial investment decision. It has been found from the literature review that demographic variables have a significant impact on the investors' attitude towards risk. From the results of chi-square analysis, Mann-Witney test and Kruskal Wallis test, it has been concluded that demographic variables do have significant impact on risk appetite for financial investment decision. It has been observed that there is a significant association between gender, age, qualification, occupation, family income (yearly) and individual income (yearly) and attitude towards risk for financial investment decision. Whereas, marital status, ethnic groups and family type do not have impact on risk appetite for financial investment decision which is controversial to the previous research (Sung and Hanna, 1997). From the literature survey, it was found that ethnic group, race and religion have no significant impact on risk tolerance level of individual (Strydom and Metherell, 2012). From the chi-square analysis and Kruskal Wallis test, it was observed that there is no significant association between different ethnic groups and risk appetite for financial investment. Additionally, it was also found that there is no significant difference between ethnic groups among attitude towards risk for financial investment decision. It was consistently observed from previous research that marital status do have impact on risk tolerance level of individual that married respondents are more risk tolerant than single respondents (Grable, 2000; Grable and Lytton, 2003; Selcuk et al., 2010). However there is a controversial finding related to marital status. The findings suggested that there is no significant effect of marital status on risk appetite of investors for financial investment decision. Majority of the studies reported that qualification plays an important role in acceptance of risk associated with particular financial investments (Anbar and Ekbar, 2010; Grable, 2000; Corter and Chen, 2005). Contrarily, other researcher did not find any significant influence of education on financial risk tolerant level (Hallahan et al., 2003; Selcuk et al., 2010; Strydom and Metherell, 2012). The finding revealed from the chi-square test and Kruskal Wallis test that there is a significant influence of qualification on attitude towards risk while making financial investment decision.

6. MANAGERIAL IMPLICATION

The findings of the study would be useful to investment managers, financial advisors and brokers/ agents. It has been observed that many researchers have studied the

relationship between demographic variables, geographic variables and socio-economic variables, which have influence on attitude of investors towards financial investment. This study provides valuable insight into how demographic variables affect an investors' subjective financial risk appetite and as such contributes to a better understanding of how individuals make financial decisions in Surat city, India. The study would help in assisting financial advisors to provide financial advice that suits the individual needs of investors. Investment managers and financial advisors can use some demographic characteristics for differentiating and classifying investors into different risk-tolerance categories. This study would also contribute to the general knowledge in the field of behavioral finance by providing some results about relations between demographics and financial risk appetite.

7. GLOSSARY

Lakh – INR 100,000
Crore – INR 100,00,000
Ethnic Group A – Hindu
Ethnic Group B – Islam
Ethnic Group C – Jain
Ethnic Group D – Others
SD – Standard Deviation

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Aquaculture Industry (Shrimp Farming): A Highly Productive Small Scale Industry for the Coastal Regions of Gujarat

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Abstract: Aquaculture industry has evolved into a major contributor to Indian economy in a short period of time in terms of the foreign exchange contributor, employment generation in rural areas and its impact on the socio economic variables in the society. Shrimp farming is turning out to be a major activity for aquaculture farmers in rural coastal areas of India, due to its high earning potential. Suitable land i.e. brackish water environment is an essential requirement for shrimp farming. Currently India ranks 2nd only to china in terms of aquaculture production, however, India's total production is only 1/20th of that of china. Underutilization of brackish water land for shrimp farming has been an area of concern. This paper is an attempt to study the potential of the coastal regions of Gujarat in terms of shrimp farming in Gujarat.

Keywords: Aquaculture, Shrimp farming, Small Scale Industry, Rural entrepreneur, Gujarat.

1. INTRODUCTION

Aquaculture is generally considered a part of fisheries science, however there is distinction between the two terms 'fisheries and aquaculture', because of some basic differences in development and management. Aquaculture is defined by The Japanese Resource Council Science and Technology Agency as:

"Aquaculture is an industrial process of raising aquatic organisms up to final commercial production within properly partitioned aquatic areas, controlling the environmental factors and administering the life history of the organism positively and it has to be considered as an independent industry from the fisheries hitherto."

Aquaculture is referred to as an organized cultivation of a crop in the aquatic medium. It includes production of an animal or a plant. Two factors distinguish aquaculture from capture fisheries:

- Intervention in order to enhance stock
- Ownership of the stock.

The traditional ways of fishing from the seas and oceans has reached to a point where the resources are reducing at very fast pace due to excessive and irresponsible fishing during the recent time. During such circumstances aquaculture production must increase in order to maintain or increase the global seafood supply per capita. Aquaculture is of great importance worldwide, serving as an alternative source to traditional food production systems to help accommodate expansion of the human population.

During the last decade there has been a global upsurge for aquaculture. Modern aquaculture has developed into a dynamic, often capital intensive business frequently controlled by vertically integrated corporate giants of the food and retail industry. There have been major increases in aquaculture productivity along the entire production and supply chain.

Aquaculture in India has a long history, there are references to fish culture in Kautilya's Arthashastra (321 – 300 B.C.) and King Someswara's Manasoltara (1127 A.D.). The traditional practice of fish culture in small ponds in eastern India is known to have existed for over hundreds of years.

Aquaculture in India, in general, is practiced with the utilization of low to moderate levels of inputs, especially organic based fertilizers and feed. India utilizes only about 40% of the available 2.36 million hectares of ponds and tanks for freshwater aquaculture and 13% of a total potential brackishwater resource of 1.2 million hectares, in other words there is room for both horizontal and vertical expansion of these sectors. With over 8000 km of coastline there is immense potential for the development of mariculture which has taken roots only in recent years with culture of mussels and oysters. The production of carp in freshwater and shrimps in brackishwater form the major areas of activity.

India is the second largest producer of fish in the world contributing to 5.68% of global fish production. India is also a major producer of fish through aquaculture and ranks second in the world after China. Fisheries sector occupies a very important place in the socio economic development of

the country. It has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries, and is a source of cheap and nutritious food besides being a foreign exchange earner. Most importantly, it is the source of livelihood for a large section of economically backward population of the country.

The fisheries sector is a source of livelihood for over 14.49 million people engaged fully, partially or in subsidiary activities pertaining to the sector. Besides, an equal number are engaged in ancillary activities in fisheries and aquaculture. Development of fisheries can ensure food security as well as tackle unemployment in these regions that are predominately inhabited by rural populace

2. LITERATURE REVIEW

B. Meenakumari from Indian council of agricultural research, New Delhi in her paper "Prospects of fisheries and aquaculture in India" studied the future prospects of freshwater and coastal aquaculture in India.

In the study of "Aquaculture: Challenges and Promise" by Peter J. Allen (2011) focuses on the food and other requirements for the culture aquaculture systems and also as how it affects the overall growth and productivity of the culture fisheries. the paper entitled 'AQUACULTURE AND ITS ROLE IN INTEGRATED COASTAL ZONE MANAGEMENT' by S.M. STEAD, G.BURNELL and P. GOULLETQUER focuses on the two main objectives: to aid the development of stronger interdisciplinary communication between the natural and social sciences and to improve the utility of available scientific information and knowledge; and to promote new perspectives on the sustainable use of coastal areas and natural resources. The paper also summarizes the debates following each of the three workshop thematic sessions: aquaculture and ICZM; socio economic and political dimensions; developing sustainable production systems; and identifies the key recommendations that may be applied to the formulation of policy on integrated aquaculture management in coastal and marine environments.

IN HIS STUDY 'AQUACULTURE DEVELOPMENT IN INDIA: A MODEL' ROYDEN NAKAMURA made an effort to identify the nationwide program implemented by India to promote aquaculture in its rural communities. The uniqueness of this programme lies in its ability to address socioeconomic and cultural factors of the society which were previously ignored by the aquacultural scientists.

3. AQUACULTURE GUJARAT: POTENTIAL AND STATUS

Gujarat is surrounded by sea from two sides and was also a part of the sea before cenezoic era. So it is obvious that the state contains inherent salinity in land and water. Tidal

amplitude of Gujarat coast is higher than other parts of West coast. This natural phenomenon has created vast stretches of marshy and saline lands all along the coast.

The coastal zone of Gujarat is widely affected by soil and water salinity. However, the nature and extent of salinity vary over the space and are directly related to the hydrology, coastal geomorphology and human interventions in the coastal region.

In addition to very low amount of precipitation, the coastal region is suffering from salinity problem due to three major reasons; namely inheritance, natural processes and manmade activities. In the areas of coastal Saurashtra and Kachchh region, the salinity has increased due to sub surface intrusion and surface ingress. Intrusion is through the extension of seawater into land aquifers, while the ingress is mainly through tidal run over on low level plains. Marine intrusion has taken place because of highly deep porous geological formation along with over withdrawal of ground water. Over withdrawal of ground water has made water table lower. This lowering of water table has resulted in saline water intrusion due to the process of reverse hydraulic gradient and capillary action.

As far as South Gujarat is concerned, the tidal water which travels upstream along river channels has not only contaminated surface water but also affected the quality of ground water due to percolation. The use of saline water for irrigation purpose makes the land saline and degraded. Soil salinity/inter alia is one of the major problems, which are being faced by the state. It is also the main reason for the severe land degradation in the coastal region. The climate of the state observes wide fluctuations during the year. The temperature varies between 2° C to 9° C in winter and goes up to 41° C to 46° C. in summer. The only source of rain for the state is the southwest monsoons.

TABLE 1: Fisheries resources of Gujarat state

Marine	
Length of coast line (Km)	1, 600
Continental Shelf ('000 sq km)	184
Number of Fish Landing Centers	121
No of Fishing villages	247
No of fishermen families	62, 231
Fisher folk population	3, 36, 181
Inland	
Total inland water bodies (lakh Ha)	4.26
Rivers & canals (Km)	3, 865
Reservoirs (Lakh ha)	2.43
Tanks & ponds (lakh Ha)	0.71
Rood plain lakes/derelict waters (lakh Ha)	0.12
Brackish water (lakh Ha)	1.00

(Source: fisheries at a glance, commissioner of fisheries, gandhinagar, Gujarat)

4. ACTS AND POLICIES FOR THE REGULATION OF FISHERIES SECTOR IN GUJARAT

- Gujarat fisheries act – 2003
- Village pond fisheries policy – 2003
- Reservoir leasing policy – 2004
- Marine fisheries policy – 2004 (GOI)
- Coastal aquaculture authority act 2005 (GOI)
- Brackishwater land lease policy – 2007

5. BRACKISH WATER LAND LEASE POLICY (REVENUE DEPT)

- Lease period for 20 years in the first instance and extendable for another 20 years.
- Lease Rent @ Rs. 250/= per ha for the first three years, which will be doubled from Forth year onwards for individual beneficiaries up to 5 Ha
- Lease rent @ Rs 1000 /- per Ha for more than 5 ha up to three years which will be doubled from fourth year onwards.
- Individual beneficiary entitled for 5 ha. Cooperatives – 50 ha and Industrial houses- 100 ha.
- Dist. Collectors empowered to sanction up to 5 Ha to individual prawn farmer, for Coop. societies limit is up to 50 Ha.
- State Govt. can sanction more than 50 Ha.
- Lessee cannot be sub leased or land cannot be transferred.
- Lessee can mortgage the land to nationalized banks and other Govt. approved financial institutions to avail loans for aquaculture activities.

6. ONGOING FISHERIES DEVELOPMENTAL PROGRAMS

- Establishment of fresh water prawn seed hatchery.
- Fish culture through FFDA's
- Fish seed Production and rearing by employing local youths
- Reservoir Fisheries Development.
- Leasing out the fishing rights of reservoirs.
- Special Programmes for SC / ST's.
- Providing landing and berthing facilities.
- Providing infrastructure facilities.
- Repatriation of fishermen from Pakistan
- Fish marketing subsidy.
- Distribution of kerosene to fishing vessels on reduced rates.
- Supply of Insulated Boxes

- Promotion of brackish water aquaculture.
- Group insurance scheme for all active fishermen
- Housing schemes for fishermen.
- Training to the personnel and fishermen
- Extension activities Good management practices
- Strengthening of Fisheries Co operatives.
- Fisheries Resource Assessment.

7. DATA ANALYSIS & FINDINGS

In India, two types of aquaculture are practiced. These are freshwater aquaculture and brackish water aquaculture.

Brackishwater aquaculture involves breeding of fish that habitat the sea like sea bass, grey mullet, tiger shrimp and mud crabs. It is practiced in States like Gujarat, West Bengal, Andhra Pradesh, Kerala and Goa. Brackish water aquaculture in India is synonymous with penaeid shrimp aquaculture. Because of its rapid growth rate and better market price, black tiger shrimp (*Penaeus monodon*) began as the most important species for penaeid aquaculture, however in recent years with the introduction of SPF L Vannamei, species of shrimp, most of the share of total shrimp production in India comes from Vannamei shrimps.

Gujarat brackishwater aquaculture sector comprises of a large number of the farms having less than 2 ha of land holding. As a result small brackishwater aqua farms are scale inefficient as the bargaining power for cost effective purchase of inputs as well as selling price is curtailed due to relative low volumes leading to low profitability.

TABLE 2: Suitable Brackishwater Aquaculture Land Available and Allotted

Sr. No.	NAME OF THE DISTRICT	LAND AVAILABLE (HA)	LAND ALLOTTED (HA)
1	Valsad	5138.73	590.31
2	NAVSARI	12037.18	1522.44
3	SURAT	19200.00	1168.50
4	BHARUCH	33208.00	1436.00
5	BHAVNAGAR	1125.00	51.14
6	AMRELI	2001.00	226.00
7	JUNAGADH	1493.00	2
8	JAMNAGAR	4104.00	0
9	RAJKOT	3200.00	0
10	KUTCHH	7834.00	0
	TOTAL	89340.91	4996.39

(Source: commissioner of fisheries, gandhinagar, Gujarat)

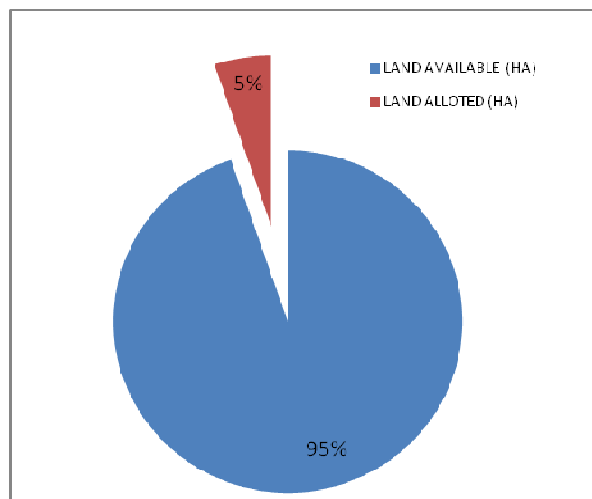


Fig. 1. Percentage of suitable land allotted in Gujarat state

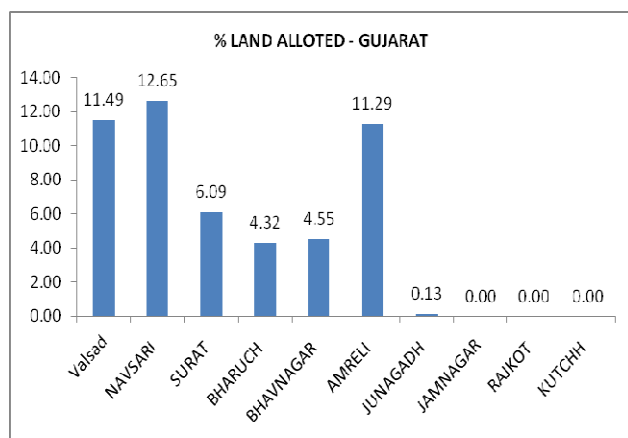


Fig. 2. Percentage of land Allotted – Gujarat State – District wise

A total of 10 districts in Gujarat have an access to brackish water land. Bharuch, Surat and Navsari are among the top three districts in terms of available brackish water lands. These land areas are underutilized in terms of aquaculture industry as the overall allotted land for the purpose of shrimp farming in Gujarat accounts to only 5%. With regards to Surat, the total percentage of land allocated to shrimp farming is about 6% only.

TABLE 3: Year wise details of Area under culture (AUC) & Estimated Production of Tiger Shrimp, L. Vannamei and Scampi (EP) for Gujarat state and India

	Gujarat		INDIA	
	AUC (Ha)	EP (ton)	AUC (Ha)	EP (Ton)
2001-02	540	680	1, 57, 400	1, 02, 940
2002-03	880	1, 050	1, 52, 080	1, 15, 520

	Gujarat		INDIA	
	AUC (Ha)	EP (ton)	AUC (Ha)	EP (Ton)
2003-04	1, 013	1, 510	1, 54, 517	1, 12, 778
2004-05	891	1, 500	1, 36, 393	1, 25, 668
2005-06	1, 297	3, 322	1, 40, 682	1, 43, 170
2006-07	1, 622	3, 227	1, 49, 632	1, 44, 347
2007-08	1, 660	3, 149	77, 079	1, 06, 165
2008-09	1, 535	3, 107	1, 08, 789	75, 997
2009-10	1, 925	3, 652	1, 02, 542	97, 650
2010-11	2, 030	6, 392	1, 16, 784	1, 36, 822
2011-12	2, 059	6, 064	1, 17, 301	2, 16, 283
2012-13	2, 359	9, 393	1, 15, 825	2, 70, 819
2013-14	2, 082	10, 688	1, 29, 444	3, 22, 684
2014-15	4426.18	30156.82	130948.7	434558.7
2015-16	4552	35499	140666	497622

(Source: The marine products export development authority – MPEDA, INDIA)

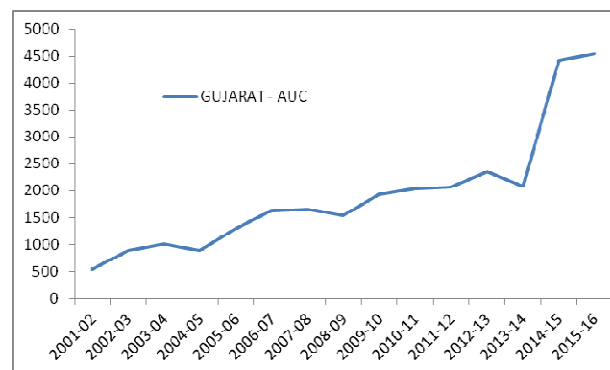


Fig. 3. Year wise Pattern of Area Under Culture in Gujarat State (Ha)

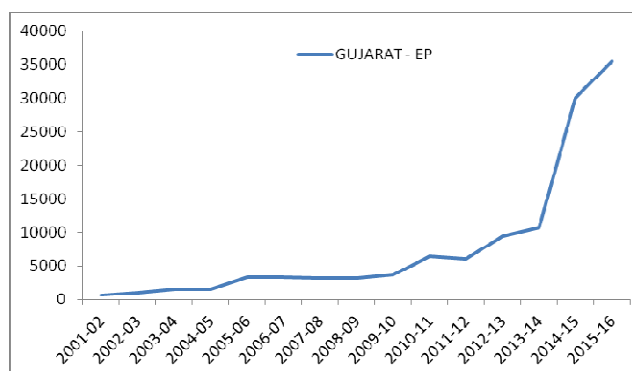


Fig. 4. Year wise Pattern of Estimated production in Gujarat State (Mt)

On a national level, Gujarat is one of the dominant states in terms of shrimp culture production. There has been an upsurge in the past few years where in the area under

cultivation as well as the overall production of shrimps in gujarat state has accelerated. Among other factors that led to this expansion, availability of SPF Vannamei shrimps seeds was a major reason as it reduced the overall risk for the shrimp farmers engaged in the farming operations

For cultivation of vannamei shrimps, as compared to tiger shrimps no extra facilities or infrastructure is required. As a result a farmer who cultured tiger shrimp earlier can easily switch to vannamei farming without and further capital investments.

TABLE 4: Productivity of Tiger & vannamei Shrimps – state wise – for year 2015 – 16

	State	TIGER SHRIMP			VANNAMEI SHRIMP		
		Area (Ha)	Prod. (MT)	Productivity (MT/ha/Year)	Area (Ha)	Prod. (MT)	Productivity (MT/ha/Year)
1	West Bengal	50, 593	61, 998	1.23	1, 387	6776	4.89
2	Odisha	4, 552	9, 191	2.02	4, 439	19, 241	4.33
3	Andhra Pradesh	2, 637	3, 739	1.42	39, 800	2, 95, 332	7.42
4	Tamil Nadu	409	1, 103	2.7	7, 615	44, 453	5.84
5	Kerala	8, 306	3, 490	0.42	22	74	3.36
6	Karnataka	1, 948	682	0.35	333	1, 045	3.14
7	Goa	0	0	0	10	33	3.3
8	Maharashtra	3	6	2	1, 356	6, 118	4.51
9	Gujarat	398	1, 243	3.12	4, 154	32, 946	7.93
	Total	68, 846	81, 452	1.18	59, 116	4, 06, 018	6.87

(Source: The marine products export development authority – MPEDA, INDIA)

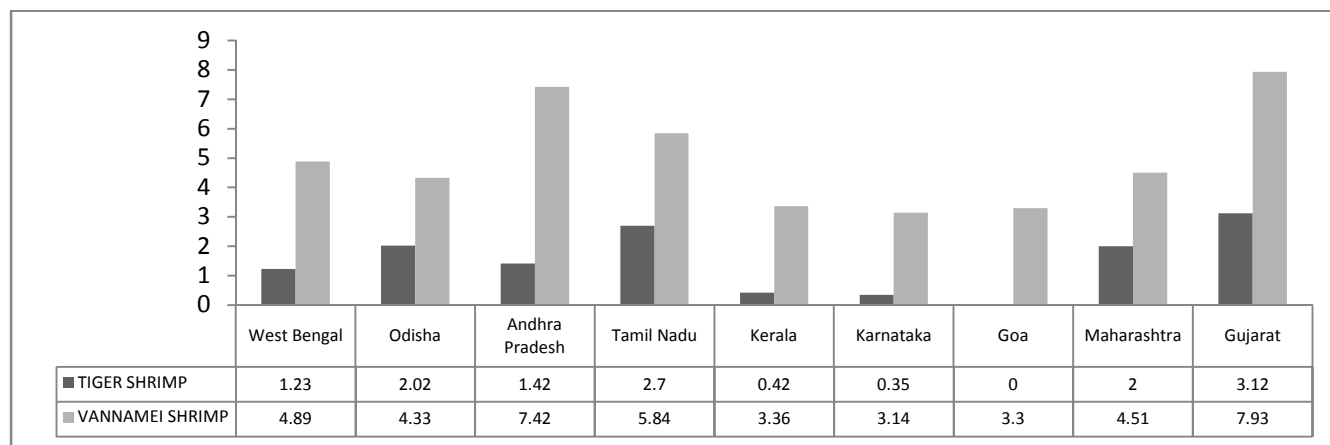


Fig. 5. Productivity of tiger and vannamei shrimps – state wise

During the initial years when the aquaculture farming practices began in India, Tiger shrimp was a major cultivable species due to its size, weight and an overall higher selling value. However cultivation of tiger shrimps is considered to be a high risk activity due to its low resistance against diseases and high maintenance during the culture period.

Vannamei shrimps on other hand eliminates this disadvantage of tiger shrimps as vannamei can be treated for SPF seeds, i.e. Specific pathogen free seeds, which makes it more stable and has a higher resistance against the diseases. This eliminates the danger of crop loss to a farmer

and there by diluting the overall risk of shrimp farming operations. As a result during the recent previous years more and more farmers have shifted from tiger shrimps to vannamei shrimps as a primary species for cultivation.

Every state of India where shrimp farming is carried out, Vannamei exhibited a higher productivity as compared to tiger shrimps. As the per hectare output improves the overall production of shrimps also increases. In the year 2015-16, where the tiger shrimps farms had a productivity of 1.18, vannamei shrimps were cultivated at a rate of 6.87 mt/ha/year. Productivity of tiger shrimps and vannamei shrimps in Gujarat state were recorded at highest level with

3.12 mt/ha/year for tiger shrimps and 7.93 mt/ha/year for vannamei shrimps.

TABLE 5: Average Productivity of shrimp farming in Gujarat & India

	AVG. PRODUCTIVITY - GUJARAT	AVG. PRODUCTIVITY – INDIA
2001-02	1.259	0.654
2002-03	1.193	0.760
2003-04	1.491	0.730
2004-05	1.684	0.921
2005-06	2.561	1.018
2006-07	1.990	0.965
2007-08	1.897	1.377
2008-09	2.024	0.699
2009-10	1.897	0.952
20010-11	3.149	1.172
2011-12	2.945	1.844
2012-13	3.982	2.338
2013-14	5.134	2.493
2014-15	6.813	3.319
2015-16	7.799	3.538

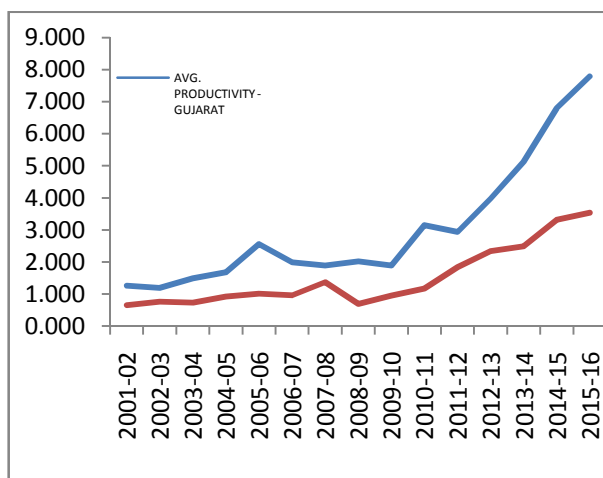


Fig. 6. comparison of productivity of shrimp farming : Gujarat - India

Gujarat has always been an out-performer in terms of shrimp productivity in India. Productivity of shrimp in Gujarat has been recorded at nearly double to that of India's average productivity. Suitable climate and better management practice among the small scale shrimp farmers in the state contributes to this improved performance.

In terms of absolute production quantity, Gujarat's total production is low as compared to states like Andhra

Pradesh and Tamil Nadu. Area under culture in Gujarat is very low as compared to these states which is a major cause for low absolute production of shrimps in the state.

TABLE 6: 3 and 5 years Moving average of estimated production of Shrimps in Gujarat.

	GUJARAT - EP	3 year MA	5 year MA
2001-02	680	#N/A	#N/A
2002-03	1,050	#N/A	#N/A
2003-04	1,510	1080	#N/A
2004-05	1,500	1353.333	#N/A
2005-06	3,322	2110.667	1612.4
2006-07	3,227	2683	2121.8
2007-08	3,149	3232.667	2541.6
2008-09	3,107	3161	2861
2009-10	3,652	3302.667	3291.4
2010-11	6,392	4383.667	3905.4
2011-12	6,064	5369.333	4472.8
2012-13	9,393	7283	5721.6
2013-14	10,688	8715	7237.8
2014-15	30156.82	16745.94	12538.76
2015-16	35499	25447.94	18360.16

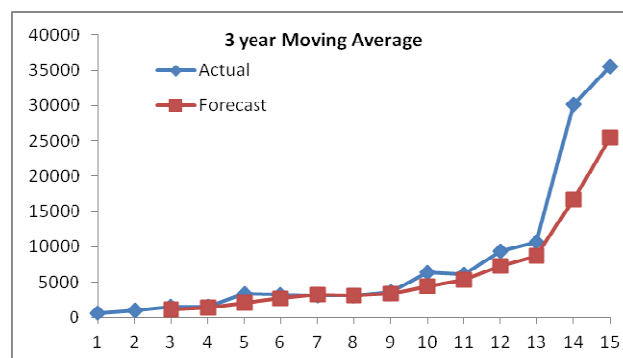


Fig. 7. 3 year Moving average of estimated production of shrimps in Gujarat.

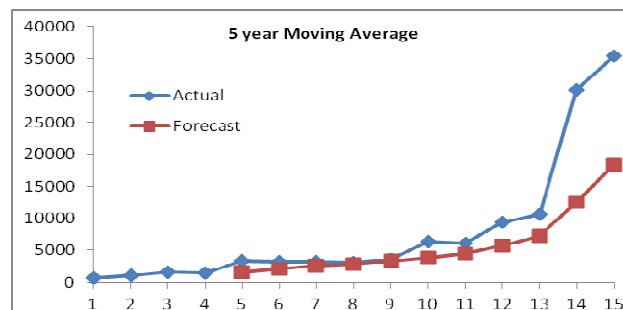


Fig. 8. 5 year Moving average of estimated production of shrimps in Gujarat.

A three year and a five year moving average charts of the estimated production of shrimps in Gujarat shows a constant and a smooth upward trend thereby indicating a further growth in the scale and production of shrimps in Gujarat. As the area under culture continues to rise, aquaculture sector in Gujarat holds high potential to emerge as a leading shrimp producer in the country. Gujarat produced more than 35,000 MT of shrimps in 2015-16, however it is only about 7% of the total production in India.

World marine fish stocks have experienced a continuous depletion over the past decade, which has led to a higher demand for cultured species of fishes to satisfy the high demand for sea food in the world. There has been a high demand for Indian shrimps in countries like USA and other European nations, which offers a huge growth potential for shrimp aquaculture in Gujarat.

8. CONCLUSION

A large area of Gujarat coastal regions possesses brackish water environment, suitable for the cultivation of shrimps. Nearly ninety thousand ha. Of brackishwater lands are available in the state of Gujarat which is among the highest as compared to other states in India. Gujarat utilizes only about 5% of the total land for shrimp farming. It indicates a huge upside potential for future development and an opportunity to convert such idle lands into shrimp farms, which would improve the overall production of shrimps in the state.

Brackish water areas due to high salinity content are unsuitable for agriculture activities, thus setting up of shrimp farms in such areas would not compete with the traditional agriculture activities in such areas.

Gujarat demonstrates highest productivity in terms of both the Tiger shrimps and L. Vannamei shrimps, so increasing area under culture in Gujarat for shrimp farming would ensure a higher production as compared to other states in India.

When the traditional methods of fishing have reached have exhausted, Shrimp farming has evolved as a major employment source of the people of coastal regions thereby improving the overall standard of living in such regions.

Brackish water shrimp farming in Gujarat acts as a small group of industrial mode of farming, where the farming area is more than 5 ha, and supported by large number of small stakeholder owning farms lesser than 2 ha who comprise around 90% of brackishwater farming community. With an increase in the shrimp farming practices, it gives rise to the development of other ancillary industries, like, feed mills, hatcheries and processing units, which further add to the overall dynamics of the aquaculture industry.

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MCADA: Building an *Intranet* of Things & People for an Enterprise-Wide Operations Control

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Abstract: In the important field of ‘Operations Control’ the emphasis of prevalent systems is either on control through expensive automation ‘of’ the operations, or on control through human-dependent sign-off’s ‘at’ their end-points. As a result, these systems offer excellent technical control and excellent procedural control. However the ‘managerial control’ aspect that calls for a ‘necessary & sufficient’ depth & breadth of coverage is not addressed well by them. Further they involve costs, complexities, &/ or pose issues related to organizational behaviour, and information overload. MCADA (Managerial Control And Data Acquisition) system (patent pending) is an attempt to define a middle path to meet that unfulfilled objective by tracking only the ‘vital few’ things & people critical-to-business at the ‘vital few’ junctures (control points) ‘across’ the operations using very simple (cost-effective) technology with an in-built enforcement of procedures. MCADA draws from the developments in ICT field of technology like the automation systems do, and also gives an enterprise-wide coverage like the Business Process Mgt Systems. However it purposely avoids deep-diving and also avoids the de-focusing due to very large coverage span. This can give to the Management an optimal & practical control over operations; in any industry – Manufacturing or other.

Keywords: Operations Control, managerial control, data acquisition

1. INTRODUCTION

In the industry, if a right game is set up by Engineering, Finance & Marketing, ‘Operations’ can make or spoil it. Having already invested in the former three, no business really has the option to allow the fourth one to spoil the game. Exactly in the same way, looking into what it takes to make ‘Operations’ successful, if the ‘Planning’ is done in the right manner, it’s the ‘Control’ that decides the end result. In essence, ‘Operations Control’ is the name of the game!

Not surprisingly therefore, it has been a focus of many great technological developments using the power of ICT, like Manufacturing Execution Systems (MES), Supervisory Control And Data Acquisition (SCADA) systems, Distributed Control Systems (DCS), etc.

The ISA S95 Standard has collated the whole gamut into a well-formed model for implementation of the above developments in a structured manner.

The point to note is that they are all developed keeping ‘Manufacturing’ as their domain. Thus they are oriented towards the factory floor. Also the method is almost exclusively ‘automation’, requiring expertise and sophistication, and therefore substantial ‘hard’ investments.

Above systems have their own place, but the Business Managers need info & control on only a few critical parameters, and they need that not only in manufacturing but across all the operations.

On another front, the developments in the Business Process Management (BPM), or Product Lifecycle Management (PLM) space offer control by providing actionable info based on ‘user’ inputs.

These solutions are of universal nature (that is they go beyond ‘Manufacturing’). Here the method is to ‘understand & assimilate the concept and learn the software’ which requires education & training (& consultancy & continuous IT support) and a disciplined culture, calling for ‘soft’ investments in addition to hard money. The approach is to automate the organizational ‘procedures’ (typically defined by the Management Systems like ISO-9001 / AS-9100 / etc.) and the ‘Control’ part is ‘considered’ as taken care of by providing a plethora of alerts in the Users’ (including Business Managers’) mailboxes. The reliability of updates depends on the ‘quality’ of user inputs. Unfortunately the much-too-familiar ‘ignore-the-alerts’ mindset or ‘oh-I-forgot-to-update’ or ‘well-I-update-everything-on-weekend’ expressions make Business Managers wary of relying on these otherwise fantastic systems (for their core purposes) for intra-day or day-to-day overall control on operations.

Looking at the above discussion, with added levels in the ISA S-95 framework as below (Fig 1), there seems to be a grey area between the ‘procedure’-focused management systems and the ‘automation’-focused technological systems, which needs to be addressed to give the Business Managers a ‘necessary & sufficient’ control over the operations across the enterprise, at reasonable cost.

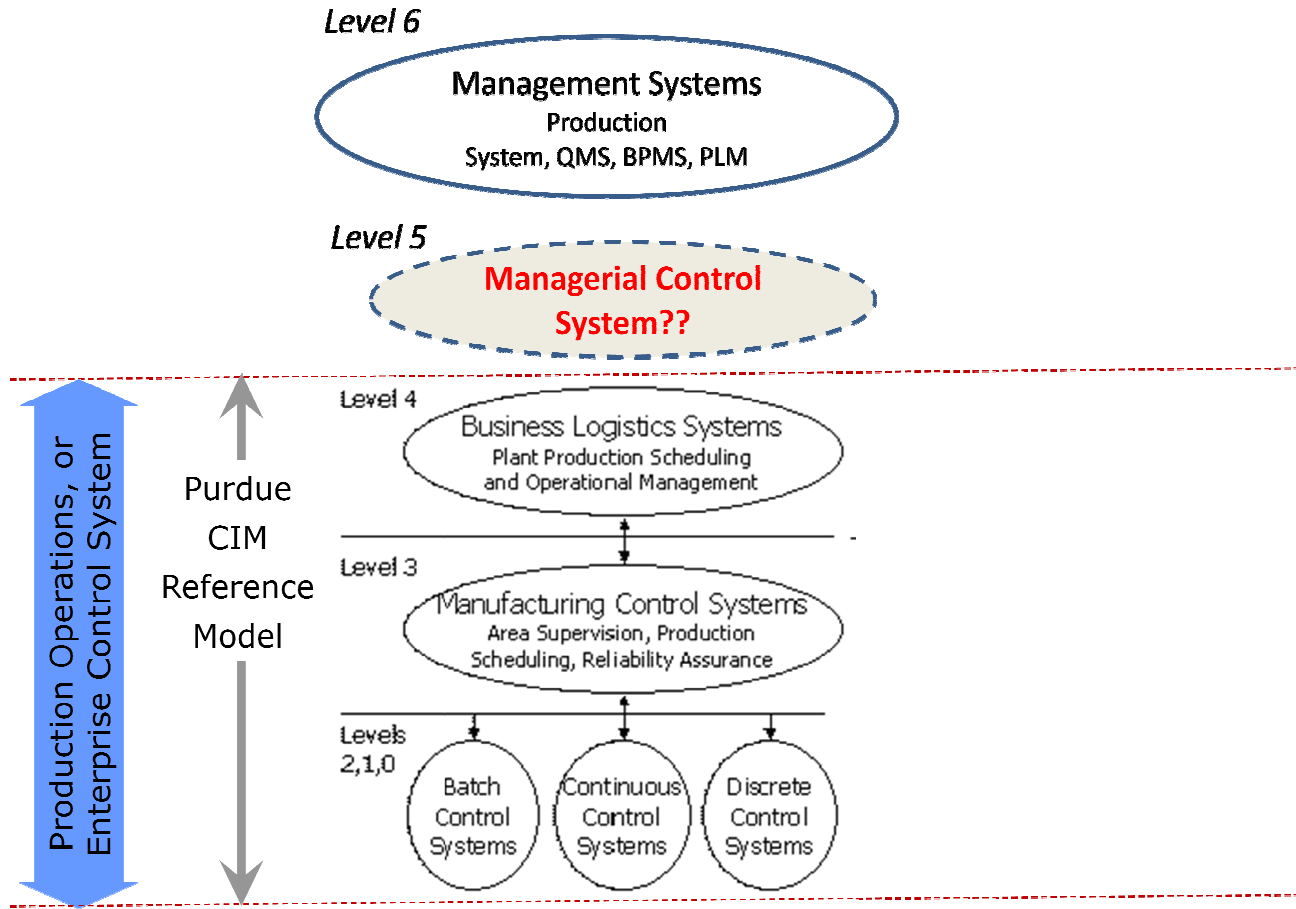


Fig. 1. Enterprise Control System (Purdue CIM Reference Model)

Managerial Control And Data Acquisition (MCADA) system is an attempt towards that, using best of both worlds i.e. the procedural neatness of the management systems (minus the human discipline related aspect) and the technological edge of the automation systems (minus the complexity & information overload), to a required extent. As the name suggests, it basically applies the Engineering fundamentals of ‘control’ used in SCADA systems but

expands the horizon beyond ‘Manufacturing’ like the Business Process Mgt Systems, by building an Intranet of Things & People.

2. LITERATURE REVIEW

The extensive literature review was carried out for Operations Control Systems which are as follows

TABLE 1: List of main Operations Control Systems

Name	Description	Reference Standard / Platform
MES	Manufacturing Execution System	SAP-CAMS (2010)
SCADA	Supervisory Control And Data Acquisition	Allen Bradley PLC (2010)
ECS	Enterprise Control System	ISA S95 Standard (2010)
AQMS	Aerospace Quality Management System	EN 9100 (2009)
PLM	Product Lifecycle Management System	PTC Windchill (2010)

3. RESEARCH METHOD

SCADA (Supervisory Control And Data Acquisition) is a representative widely-used control system in the industry, which is taken as the reference to understand the fundamental elements of control systems required in the industry.

3.1 Fundamentals of 'Control'

Let's take a look at a very common example of (an analog) control (Fig 2).

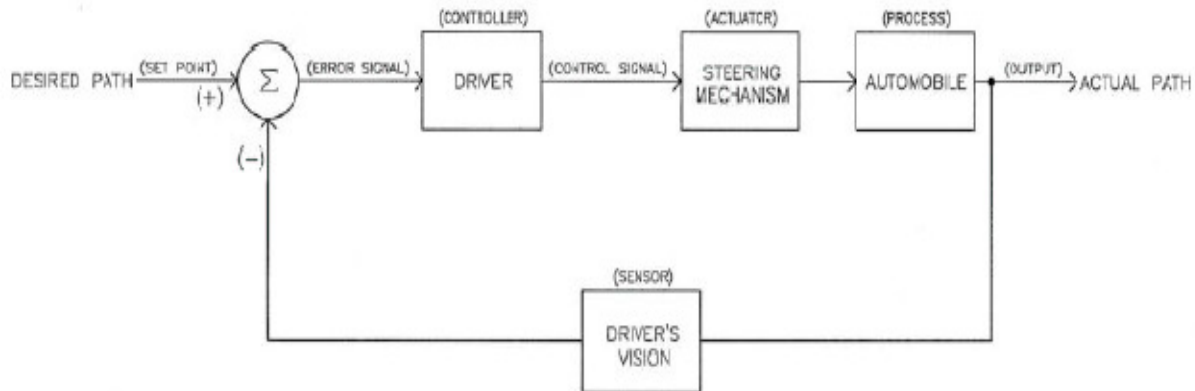


Fig 2 A basic Control System

Point to note is that to control a process we need a sensor to send an error / deviation signal if any, a controller who notes the error/deviation signal (w.r.t. a set point) and issues a control signal in response, and an actuator to make course correction happen.

Let's look at a more technical process control example (Fig 3)

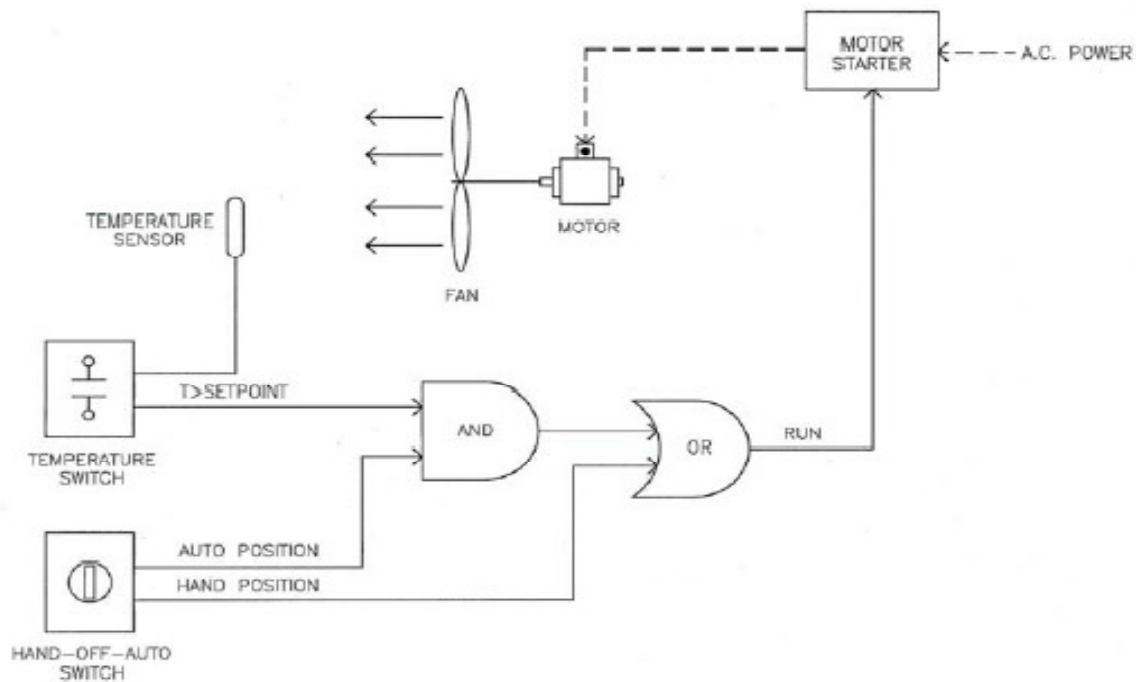


Fig. 3. An advanced Control System

Again, the essential components (sensor, controller and actuator) remain the same with the addition of a logical electronic circuit to automate the things not requiring human intervention, (though providing for a manual override).

3.2 SCADA: Supervisory Control and Data Acquisition system

Let's now look at the real sophisticated example which is nothing but the SCADA (Fig 4).

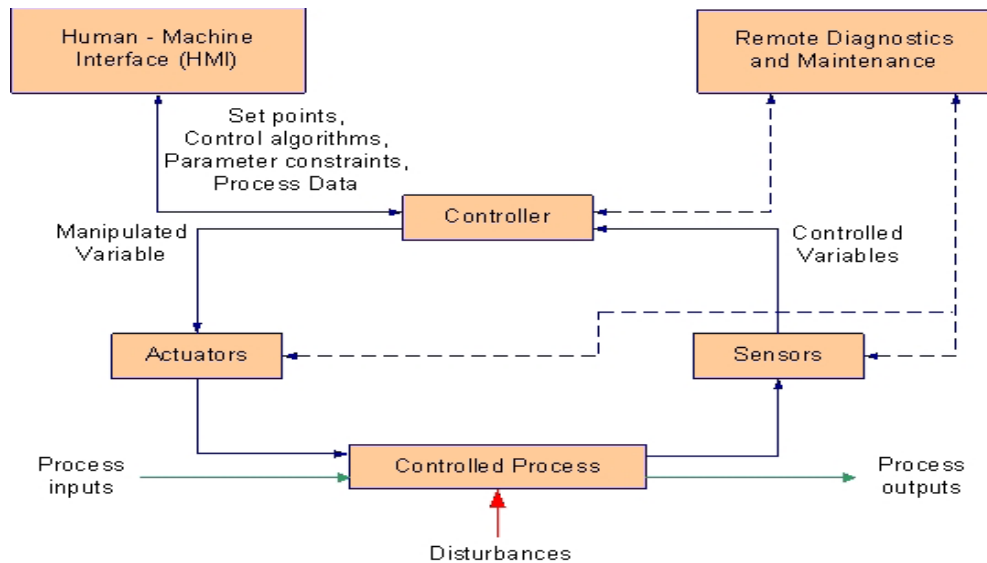


Fig. 4. SCADA Architecture

This is how Engineering control grows in sophistication (albeit with some real cost implications).

4. MCADA: MANAGERIAL CONTROL AND DATA ACQUISITION SYSTEM

MCADA, the suggested Managerial Control System, is about picking up threads from the above progression, and applying it to 'operations control'. It's kept lean (and low-cost) by monitoring minimal parameters to gain an optimal control on all operations in a unified manner.

MCADA works on some fundamental aspects of operations as follows.

In operations, there happen to be two 'things' : 1) there is 'work', and 2) there are resources. The work moves from one resource to other (or vice versa), travelling (actually or virtually) from one workplace to another in that process.

The key to control operations therefore is to know where are these two 'things', and to make course corrections if/as required.

MCADA proposes a control mechanism to achieve that objective using some very simple means. A typical schematic arrangement looks as below (Fig 5).

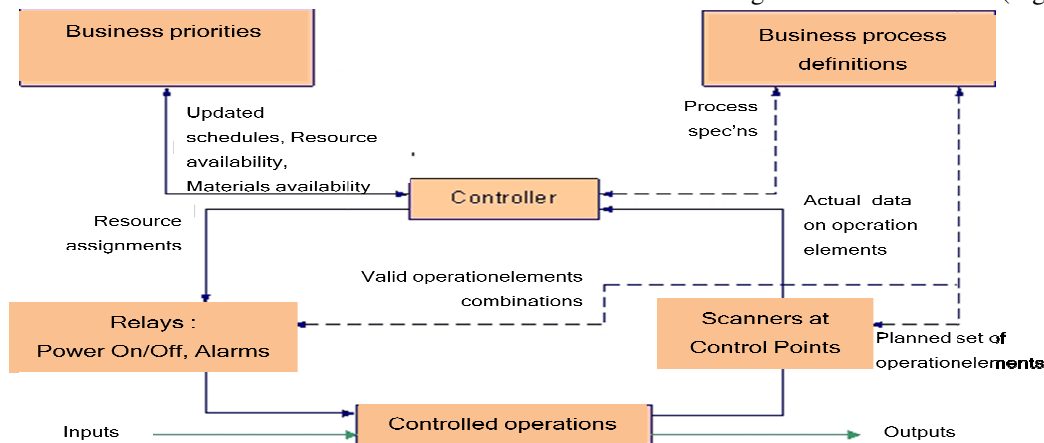


Fig. 5. Schematic diagram of the proposed MCADA system

The ‘controllers’ define the ‘control points’ under their respective area (manufacturing, purchase, HR, Logistics, etc.) across the Value Chain. A simple technology like BarCoding is then used to collect information about presence of ‘things’ at those ‘places’. So, that way it is akin to building an *Intranet* of Things. The differentiating part however is that in MCADA, unlike IoT, we use organizational behaviour as the driving force rather than the technology, as explained in the working as below.

4.1 The principle of working:

MCADA requires all critical ‘things’ (including ‘people’) to be assigned ‘info-tickets’ with BarCodes, and all the ‘Control Points’ to be assigned ‘info-seat’ BarCodes. The system then tracks the movement of the ‘info-tickets’ across various ‘info-seats’. For example, a typical set can be as below:

Thing	Owner	Info-ticket	Info-seat
Materials (WIP)	Custodian	Work Order BarCode	Workstations, Delivery points
Employee	Self	Employee BarCode	Work-stations

4.2 The method of working:

Step-1

The ‘controllers’ issue info-tickets to people. A pre-decided set of info-tickets is scanned in a pre-decided sequence at the start of each operation at a ‘control point’. In the event of incomplete or incorrect data from actual scans, some optional hard controls are deployed, like appropriate relays to actuate / not actuate the respective machines so that the operation cannot be performed.

Step-2

At the end of each operation, again a pre-decided set of info-tickets is scanned to declare the completion of operation. Again, optionally the power supply to the respective machines can then be stopped, so that the next operations can start only after the required set of scans take place.

Step-3

The ‘controllers’ assign next operation to the people thus freed from the current operation. This can be done in advance if a certain schedule can be drawn, or can be done dynamically.

Step-4

The alerts on the next operation time & assignment are sent to the respective people, and also to the easily viewable display & alarm screens across the establishment.

Step-5

This is the most critical step that mandates the current

owner of the ‘info-ticket’ to transfer it to the next assigned owner. Until the next owner has taken ownership and declared so by scanning, the ‘info-ticket’ is stuck with the current owner (even though s/he may have completed the operation).

In case of disputes related to a person not ready to take custody due to any other reason than being already fully occupied, the info-ticket is handed over (again through a Scan) to the predecessor’s Manager who has to resolve it till it is handed over to the expected successor.

Refusing to take custody due to sufficient work available on the plate would actually be good, to implement the ‘pull’ system (ref : Lean thinking), and to highlight capacity issues if any.

Till the time the operation is not declared as completed, the Cycle Time is being clocked. Once the operation is declared complete, till the custody has not changed, the Flow Time is clocked. This gives vital inputs to the Production System Analysts / Industrial Engineers / Lean Experts.

Step-6

Additionally, the non/conformance to expected ‘form’ of the product at pre-defined junctures may be captured through login-controlled BarCode scans by QC people.

4.3 The ‘operations control’ through MCADA is achieved with three on-line PTP reports:

Basically there are two simple rules of this system :

- 1) the system is kept ‘aware’ of every ‘thing’ as being under the custody of some ‘person’, and as being at some ‘workplace’ (machine location, PC, Canteen, Security Gate, Training Centre etc.), always;
- 2) every change in custody is forced to be declared to the system by scanning of 3 BarCodes, associated with - i) the thing, ii) the person taking custody, iii) the workplace (machine, PC) where the hand-off happened.

Once the above is ensured, there are three reports that keep the operations under control.

- 1) *Display & alarm report flashed on screens* at prominent locations keeping the work assignments loud & clear to every-one, supported by individual SMS alerts, forming a visibility-pressure & no-excuse culture
- 2) *Snapshotreportfor managers* about which info-ticket is at which info-seat at the moment, colour-coded for deviation from plan, putting positive pressure to monitor & resolve deviations, making their core job easier to perform

- 3) *Timelinereport for individuals (& their managers)* on their own travel, the travel of info-tickets in their custody, again colour-coded for the On-Time performance

In addition, to enforce the discipline, a report about all the info-tickets in possession of a person is displayed along with colour-coding at the time of entry / exit swipe of attendance system every day. Appropriate rules are put in place so that the colour-coding serves as OK (Green), Warning (Yellow) or Action (Red) signals. The 'Action' could be to disallow attendance at certain level of Red signals.

(Some other positive incentivising may be built, like small rewards for being in Green always.)

4.4 "Business First" approach

As can be seen from above working, MCADA takes a "Business First" approach. It's a Business System first, and IT System later.

Like typical IT Systems, it DOES NOT 'focus' upon - 'modernization', 'integration platform', 'extracting more from ERP system', 'automation', 'scalability', 'downloading production orders from ERP', 'uploading production status to ERP', 'plant floor data management', 'workflow management', 'integrating ERP with Plant Systems', 'standard certified components reducing project risk', 'HMI' and so on; while it DOES provide similar benefits w.r.t. - 'traceability', 'genealogy', 'up-to-date inventory records', 'greater visibility & control', 'reduced lead time', 'increased throughput & product quality', 'improved labor utilization', 'regulatory compliance', 'environmental efficiencies', 'energy utilizations',

'optimizing manufacturing processes', 'operations logbook', 'technical parameter limits management', 'equipment life', 'incident reduction', 'KPI monitoring', 'SPC', 'OEE', and so on.

4.5 The cost factor

The cost of printing the BarCodes is very low, however the cost of Scanners may become an obstacle, if we need them in large numbers. Hence the alternative is SmartPhone Apps that can scan the BarCodes and upload the transaction details to the Server.

5. RESULTS, DISCUSSIONS, CONCLUSIONS AND FUTURE SCOPE

The prevalent IT Systems in Operations Management or Control domain, are typically an expansion of business by Automation providers into this domain, and thus have the same underlying focus. MCADA, being designed by IE & Lean experts, takes a much broader & higher viewpoint, so does not get into EWI or other controls where human intelligence under alert supervision and a bit of mistake-proofing can produce desired results. (Remember 'Autonomation'?!). Hence implementing MCADA or sustaining its implementation does not require Automation or ICT specialists.

MCADA system is designed (refer Fig 6) to collect minimal field information, transfer it to a central computer server, processed by a human controller or by a controller software, allowing the controller to monitor or control the entire enterprise system from any location in real time. The feedback from the controller (if any) is reflected in alerts displayed and sent to the managers or operators.

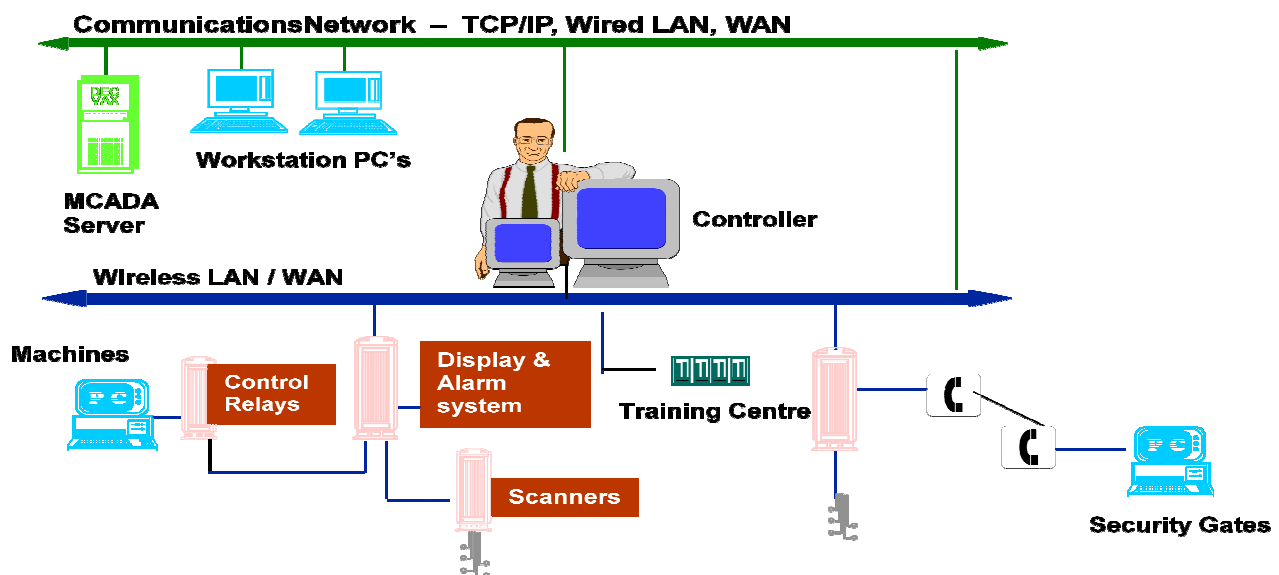


Fig. 6. Proposed MCADA Architecture

5.1 MCADA: Key Business Benefits

- 1) It's a novel concept. It provides a unified and objective method for an enterprise-wide control over ALL business operations. It controls the Enterprise in the same perfect manner in which a SCADA system controls a machine. It's configurable in the same way, reachable from across the globe, and reliable.
- 2) The key value-adding aspect of MCADA is that it tracks the movement of things & people in Time & Space throughout the value chain. The other key aspect is it puts the Lean philosophy in practice across the organization by building in Lean practices like 'Pull', 'Kanban', and 'Andon' into the operating system.
- 3) MCADA takes the lateral view of the business operations. While it is good to take the sequential or horizontal view when converting the business plan into tasks or jobs (the 'what' & 'how' & 'when' part), when it comes to control, it works better to monitor the 'time-table' resource-wise (the 'who' is 'where' & 'when' part). The reason for this is that the execution can falter because of the resources, unless the plan is bad in which case we need to go back to the drawing board and change the plan. In the latter case too, it's the feedback from the resource performance that can take us to that conclusion.
- 4) MCADA improves resource efficiency through constant visibility (literally through IP Cams if required) and therefore pressure on the resource users (or on the resources themselves, in case of people) about the work pending with them and about the speed expected. MCADA also improves 'managerial effectiveness' as the managers know where to pay attention when.
- 5) MCADA on purpose avoids diving deep 'inside' the business operations, thus remaining lean and generic in its applicability, attaining unified system and quick

business benefits without the complexities of managing any high-end technologies.

5.2 Conclusion

Being a lean & a generic solution, MCADA is applicable in any industry wherever 'operations' exist i.e. wherever the work flows from one workstation to another and is being worked upon by resources (including human). MCADA is not about collecting process data e.g. clinical data is not the subject matter of MCADA, it's the operations data - i.e. which patient was administered which dose at what time by whom in which room - that is maintained & controlled through MCADA. Hence MCADA can provide for a much-needed simple & enforceable tool for the Business Managers giving them the 'necessary & sufficient' and 'reliable' real-time info so that they can be on top of 'Operations' without bothering about their types & technicalities.

Therefore MCADA fills the gap (pointed out in the preamble) above Level-4 of ISA-S95 model and below the *Level-6 we added (Fig 7)*. The good part is that it draws info directly from Level-0, 1 & 2 utilizing existing controls or otherwise introducing very simple controls of its own. At the same time, it's not in conflict with other existing systems, in fact it can draw benefits out of it. For example, typically in large enterprises the Work Orders may be generated from ERP and used by MCADA. However, what MCADA really needs that they carry a BarCode. So, like in Small & Medium Enterprises, the WO's may be print-outs from an amateur Excel-based system. Thus MCADA provides a sort of fly-over from Level-0 directly reaching beyond Level-4! Of course, you can always take the road through Level-3, 4 if already built and continue to reap the benefits thereof. Further MCADA is not only about Manufacturing Operations, it can work equally well beyond Manufacturing. Thus MCADA goes beyond ISA-S95 scope by covering ALL business & supporting operations (like even including management of security, etc.). The diagram below summarizes the unmet need MCADA fulfils.

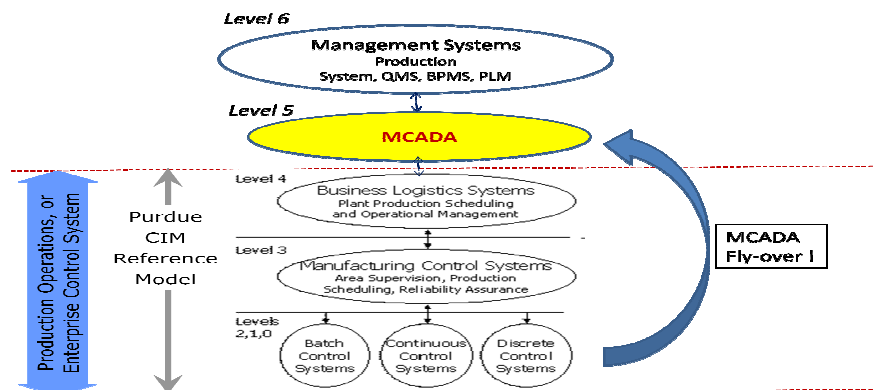


Fig. 7. Positioning MCADA in the Business System

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A Review of Poisson Distribution for Better Understanding towards Newer Applications

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Abstract: The three major discrete distributions that use integer as random variable are Binomial, Poisson and Hypergeometric distributions. In this study, we primarily discuss about Poisson distribution which was discovered by Simeon-Denis Poisson in 1838. The applications of Poisson distribution in science, real world and more specifically related to healthcare services are described in detail. This is followed by a review of properties of Poisson distribution inclusive of certain higher order moments. Different type of Poisson distributions and their properties along with their applications are described in brevity. A section on methods to generate Poisson-distributed variables as well as a few methods like maximum likelihood, confidence interval for estimation of its key parameters has been briefly elucidated. Finally, distributions that can approximate Poisson along with certain distributions that Poisson distributions can approximate have been discussed to give the reader a wholesome view about this distribution.

Keywords: Approximations, Distributions, Health Care Applications, Poisson.

1. INTRODUCTION

Poisson distributions, named after Simeon Poisson are statistical tools that help in predicting the probability of certain key events that can happen, provided we know often how the event occurs in the past. Hence it gives the

probability that events can happen in an interval of fixed time. All the real-life situations where Poisson distribution plays a pivotal role always have some identifiable characteristics. Poisson distributions can also be generated from certain statistical experiments known as Poisson experiments. The Poisson probability is given by

$$P(x, \mu) = \frac{e^{-\mu} \cdot \mu^x}{x!} \rightarrow \text{①}$$

where $P(x, \mu)$ is the Poisson probability that there are x successes in a Poisson experiment, μ is the mean of number of successes that occurs in a specified region and period, x is the actual number of successes is occurring in a specified region and period and e is the base of natural logarithms and is a constant equal to 2.718. Success means any outcome that is being in the question that occurs. The various events need to be independent for the Poisson distribution to be applied i.e. if occurrence of one event does not affect the other event. It can be proved that the mean of Poisson distribution as well as the variance is equal to

The Poisson probability that is represented by equation 1 is also known as probability mass function. A close relation occurs between the Poisson distribution as well as the Exponential distribution whose description is given below.

“The number of occurrences of an event within a unit of time has a Poisson distribution with parameter μ if the time that has elapsed between any two successive occurrences of the event has an exponential distribution with parameter μ and that is independent of previous event occurrences.” (Ref: Statlect: The digital textbook). This can be expressed by the following example.

Consider that a sequenced random variable that follows the Poisson distribution i.e. a set of arriving phone calls that the specific call centre receives. If any time that elapses between two consecutive phone calls is following an exponential distribution and the time of arrival is independent with reference to all previous calls, then calls that the call centre is receiving in one hour is following a Poisson distribution. The concept is illustrated by the plot shown in Figure 1 below, a graph is plotted between time and calls received. The function in the graph makes a jump

in the upward direction each time on the arrival of a phone call. The time that is being elapsed between two consecutive phone calls follows the exponential distribution that is equal to the prescribed length of each horizontal segment in the figure 1 shown below. The call count that was being on the receiving end in 60 minutes follows a Poisson distribution and is highlighted by the curly brace.

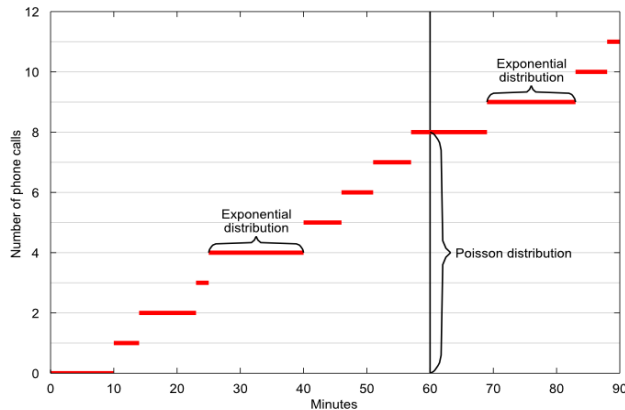


Fig. 1

In the following section, we look at some of major applications of Poisson distributions in science and real world with specific focus on its health care based applications. In section 3 we look at properties of Poisson distribution, including some techniques, like adding two Poisson distributions that would be helpful in production, specifically in dealing with problems involving multiple assembly lines. Section 4 deals with diverse types of Poisson distributions. Section 5 briefly discusses about certain methods like maximum likelihood method for estimating parameters of Poisson distribution. Section 6 briefly describes about the software and commands that are used in software to generate Poisson distributions. The concluding section deliberates on certain approximations towards other distributions like binomial that Poisson distributions can be used for as well as certain other distributions that are approximations for Poisson distributions. By study of this paper, the author's intention is that both the novice and advanced reader in statistics gets a comprehensive view of this amazing distribution's power to apply in more new and sophisticated industrial applications.

2. SOME REAL WORLD AND SCIENTIFIC APPLICATIONS OF POISSON DISTRIBUTION

The purpose of this section of the paper is to bring about a cognizance of various applications of Poisson distribution and the opportunities it provides in real world cases.

Patients who are arriving at an well-equipped and designed emergency room, cars that drive for petrol to a petrol station, decaying of rays of radioactive atoms, a queue of

bank customers arriving at a bank, and finally shoppers being served at a cash register. All these events follow a Poisson process. For few more Poisson related examples, we have the following (Jerzy Letkowszki)

- Prussian Army soldiers killed by horse kick, though accidentally in a year (von Bortkewitsch, 1898, p. 25).
- Monthly bankruptcies filed. (Jaggia, Kelly, 2012 p.158).
- Car-washing of cars arriving. (Anderson et al., 2012, p. 236).
- Network failures that have occurred in a year (Levine, 2010, p. 197).
- Hungry persons entering McDonald's restaurant.

The above time-based Poisson variables are extremely popular in contrast to space oriented Poisson variables which are described below. (Jerzy Letkowszki)

- Fleas accumulated on top of a dog (Levine et al., 2011, p.).
- White bond paper blemishes. (Doane, Seward, 2010, p. 232).
- Bacteria multiplication. (Anderson et al., 2012, p. 237).
- The number of defects in a 50-yard roll of fabric or the number of bacteria in a specified culture (Jaggia, Kelly, 2012, p.158).
- Hazardous based waste sites in a country (Black, 2012, p. 161).
- Eagles that nest in a specific region (Triola, 2007, p. 252-253).
- Customer complaints on a service on a monthly basis (Donnelly, Jr., 2012, p. 215).
- Visitors on WWW per minute (Sharpie, De Veaux, Velleman, 2010, p. 654).
- Consumer hot line calls arriving in a 2-minute time period (Pelosi, Sandifer, 2003, p. D1).

Poisson distributions are extensively used in health care industry and hospitals. The phenomenon of variability, though not similar to automobile or production industry exists in health care industry also and the process of reducing variation improves both throughput and quality in delivery of the healthcare services. Here variation occurs, when random arrival of patients for some emergency situations results in scarce resources in the hospitals. The arrival of patients follows a multiple or compound or truncated Poisson distribution that is discussed in subsequent sections of the paper. Thus, an availability of mean arrival rates and its natural variability are extensively

used for planning of resources. Some complex problems involving patients who were not scheduled in the workload, randomly arriving patients, not enough number of ICU beds, OR Rooms, health staff etc. lead to lowering of efficiencies, high error rates leading even to many fatalities. Fortunately, a systematic study inclusive of queuing analysis, arrival patterns of patients can be safely said in following Poisson distributions and Poisson based regressions that have been of immense help in reducing these critical problems.

In some of the other major applications in health care, a few hospitals that have studied the admissions through its Accident and Emergency department to the ICW and MSW, have shown that the queueing model that has been selected, assumes that the daily admissions rate follow a Poisson distribution and this behaviour was confirmed here by goodness of fit test as illustrated in the following Figure 2. The arrival rate into Intensive Care Unit follows a Poisson distribution was proved by Green L.V(2002) and Milne and Whitty (1995). The occupancy rate (ρ) was found to be in correlation with the actual demand (λ) and hence LOS (μ) which can be defined as follows, $\rho = \text{Mean beds occupied} / \text{number of beds available} = (1 - P_c) \lambda \mu c$. The term $(1 - P_c)$ can be called as the absolute demand, as the admissions that have been refused can be subtracted from the actual demand. Also, $\lambda \mu$ is the final product which

is expected number of patients in the system, that is also represented by workload of the current system.

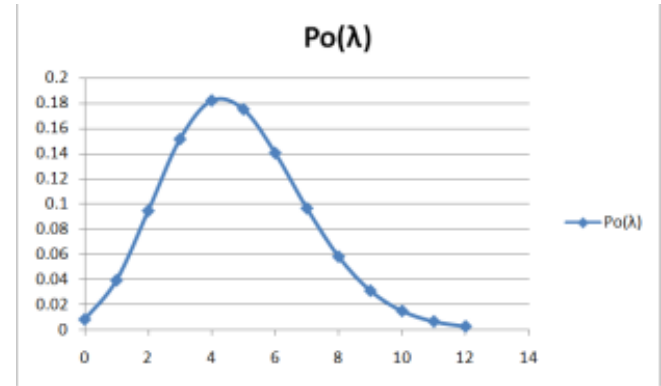


Fig. 2. Distribution depicting arrival rates in the system

Another major area where the Poisson distribution has been extensively applied and where it makes easy is in estimation in the number of births on a daily basis that can be used in planning the staff of obstetrics clinics whether it is of small or enormous size will not be an issue. An exemplification of different sizes of obstetrics clinics be it small, medium or large is shown in Figure 3 with births number on X-axis and Y-axis depicting density indicating the Poisson distribution in Red and green representing normal distribution.

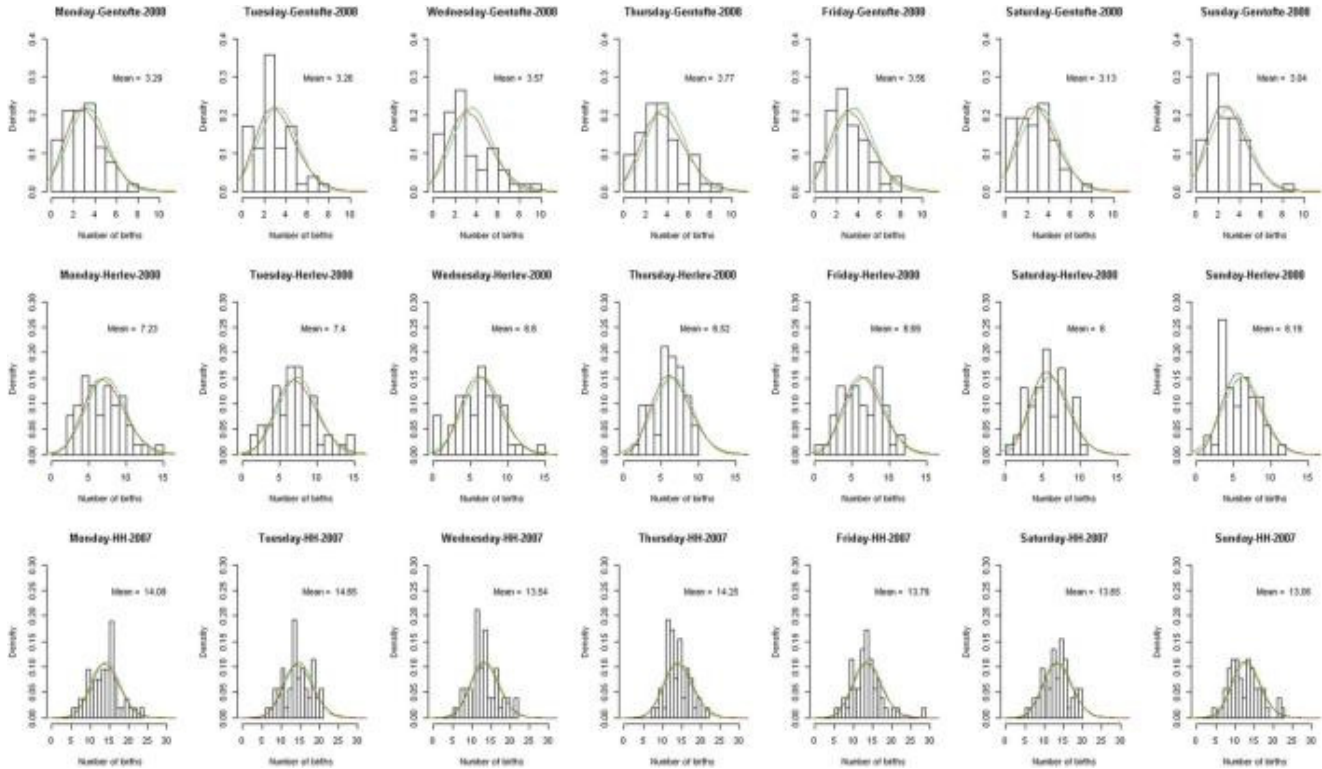


Fig. 3.

3. PROPERTIES OF POISSON DISTRIBUTION

3.1 Expected Value of Poisson Distribution (or Random Variable):

For any given discrete random variable that is following a Poisson distribution having parameter the expected value of this variable is $E[X] = \lambda$

3.2 Variance of Poisson Distribution (or Random Variable):

For a given discrete random distribution and a variable X that follows a Poisson distribution having parameter the variance of this variable is $\text{Var}[X] = \lambda$.

3.3 Mode of Poisson Random Variable:

If λ is not an integer, the mode of a Poisson distribution having parameter λ is $[\lambda]$

Otherwise, both λ and $\lambda - 1$ are modes.

3.4 Median of Poisson Random Variable:

The median P of a Poisson distribution with parameter λ satisfies

$$\lambda_{\ln 2} \leq P \leq \lambda$$

3.5 Sum of two Independent Poisson distributions (or Random Variables):

Let X_1 as well as X_2 be the two Poisson random distributions or variables having parameters λ_1 and λ_2 , respectively. If X_1 as well as X_2 are independent, then $X_1 + X_2$ is also a Poisson distribution or random variable with parameter $\lambda_1 + \lambda_2$

Its distribution can be described with the formula

$$P(X_1 + X_2 = k) = \frac{(\lambda_1 + \lambda_2)^k \cdot e^{-(\lambda_1 + \lambda_2)}}{k!}$$

The above proof can be shown as below.

Let $X = Y + Z$,

we have now $P(X = x) = P(Y + Z = x) =$

$$\sum_{y+z=x} P(Y=y, Z=z)$$

$$= \sum_{y,z=0}^{\infty} P(Y=y) P(Z=z)$$

$$= \sum_{y=0}^{\infty} \frac{e^{-\lambda_1} \lambda_1^y}{y!} \sum_{z=0}^{\infty} \frac{e^{-\lambda_2} \lambda_2^z}{z!}$$

$$\begin{aligned} \text{Now } \frac{\lambda_1^y}{y! z!} &= \frac{(\lambda_1)^y}{y!} \frac{(\lambda_2)^z}{z!} \\ \text{or } P(X=z) &= \frac{e^{-\lambda_1} \lambda_1^y}{y!} \frac{e^{-\lambda_2} \lambda_2^z}{z!} \\ \text{from binomial theorem} \\ \text{last sum is } (e^{-\lambda_1} \lambda_1 + e^{-\lambda_2} \lambda_2)^z \\ \text{or } P(X=z) &= \frac{e^{-(\lambda_1 + \lambda_2)} (\lambda_1 + \lambda_2)^z}{z!} \end{aligned}$$

Therefore, X has a distribution following Poisson with parameter $\lambda_1 + \lambda_2$.

4. SOME TYPES OF POISSON DISTRIBUTIONS WITH THEIR APPLICATIONS

One of the major types of Poisson distribution is the bivariate Poisson distribution which has been extensively used in modelling sports related data which has two outcome variables. Bivariate distributions are used primarily as it allows dependence between two random variables.

The other type of Poisson distribution is multivariate Poisson distribution that has been essentially been used in numerous applications, some of them are multi echelon based supply chain distribution systems, multi-item as well as multi-period pricing and costing models, as well as effective accident monitoring systems, etc. To set the pricing of non-durable products like for example (e.g. cosmetics, certain perishables like fashion, supplies in an office) on a definite as well as finite, multi-planning time period has been a nontrivial problem and it has been found that simulation based on multi variate Poisson models has been extremely useful for such type of models. Another major application of multi variate distributions is in bio-surveillance. A major aspect of bio-surveillance is an early and absolute time based detection of chronic disease based outbreaks. A major feature and quality of bio-surveillance data is that it exhibits multiplicity in numerous dimensions, inclusive of factors as multiple data sources (e.g. pharmacy and sales of medicine, hotline calls regarding availability of nurses, and emergency based department visits), multiple available locations (e.g. different hospitals within a certain and provided geographical area), multiple symptoms of various diseases, etc. Multi-variate monitoring, hence is

receiving a phenomenal attention and hence bio-surveillance data has also been placed on radar in literature.

5. METHODS FOR ESTIMATING PARAMETERS OF POISSON DISTRIBUTION

In many problems, we come across a situation where it is not that clear on what type of estimators are appropriate for a distribution, but still there are a few methods to derive the estimators and we will consider the methods that are useful for estimation of Poisson distribution. They are usually 1) the maximum likelihood method as well as 2) the method of moments. Though the method of moments may look simpler, it is the maximum likelihood method that provides better estimation.

The maximum likelihood estimator of say Poisson distribution having a parameter λ can be written as below

We Poisson distribution

$$f(x) = \frac{e^{-\lambda} \cdot \lambda^x}{x!} \quad (x=0, 1, 2, \dots)$$

and normally $\frac{d}{d\lambda} f(x, \lambda) = 0$

$$\text{Max}(l(\lambda)) = \frac{d(l(\lambda))}{d\lambda} = 0 \quad \text{or}$$

$$\lambda - \frac{\sum_{i=1}^n x_i}{n} = 0 \Rightarrow \lambda = \frac{\sum_{i=1}^n x_i}{n} = \text{mean}$$

Thus, we see that maximum likelihood estimator λ is just the sample mean of n observations in the provided sample.

The method of moments also estimates multiple moments of a distribution and here in this section we show how we have come up with first, second and third moments of Poisson distribution having a parameter

First Moment of Poisson Distribution

$$\begin{aligned} \mu_1'(\lambda) &= \sum_{x=0}^{\infty} x \cdot \frac{e^{-\lambda} \lambda^x}{x!} \\ &= e^{-\lambda} \lambda \left[1 + \frac{\lambda}{2!} + \frac{\lambda^2}{3!} + \dots \right] \\ &= e^{-\lambda} \lambda \cdot e^{\lambda} \\ &= \lambda \end{aligned}$$

Second Moment of Poisson distribution

$$\mu_2'(\lambda) = \sum_{x=0}^{\infty} x^2 \cdot \frac{e^{-\lambda} \lambda^x}{x!}$$

$$\begin{aligned} &= e^{-\lambda} \lambda^2 (1 + \lambda + \lambda^2 + \dots) + \lambda \\ &= e^{-\lambda} \cdot \lambda^2 \cdot e^{\lambda} + \lambda \\ &= \lambda^2 + \lambda \Rightarrow \mu_2'(\lambda) = \lambda^2 + \lambda \end{aligned}$$

Third moment of Poisson distribution is $\mu_3'(\lambda) = \sum_{x=0}^{\infty} x^3 P(x)$

$$\begin{aligned} &= \sum_{x=0}^{\infty} \{x(x-1)(x-2) + 3x(x-1) + x\} P(x) \\ &= \lambda^3 + 3\lambda^2 + \lambda \end{aligned}$$

$$\begin{aligned} \text{or } \mu_3 &= \mu_3'(\lambda) - 3\mu_2'(\lambda) \cdot \mu_1'(\lambda) + 2(\mu_1'(\lambda))^3 \\ &= \lambda^3 + 3\lambda^2 + \lambda - 3(\lambda^2 + \lambda)\lambda + 2\lambda^3 \\ &= \lambda \end{aligned}$$

Thus, we see first, second and third moments are the same for Poisson distribution and is equal to the parameter λ . The derivations in this section gives the reader for estimating the parameters of our Poisson distribution using moments technique and likelihood function. This will aid the reader to apply these estimation techniques specifically for the applications and problems involving samples that follow Poisson Distribution.

6. SOME APPROXIMATIONS

In the concluding section of this paper, the author provides a terse review of approximations under which Poisson distribution acts as an approximation to binomial distribution. When in binomial distribution becomes large i.e. as 'n' approaches to infinity ($n \rightarrow \infty$), 's' tends to zero ($s \rightarrow 0$), then $n \cdot s$ which is the mean, tends to a constant.

Then, the binomial probability mass function which is $\frac{n!}{x!(n-x)!} s^x (1-s)^{n-x} \rightarrow \frac{e^{-\lambda} \lambda^x}{x!}$ which is the Poisson distribution.

This is also known as Poisson Limit Theorem. Normal distributions are also extensively used for approximating

Poisson distributions when the parameter λ becomes large. These approximations give a more accurate picture while performing the hypothesis tests as they are also rational in the approach. Further it has already been found out that the approximations for Poisson distributions has been very effective in single period inventory model. This makes the use of approximations in real world applications more beneficial.

7. CONCLUDING COMMENTS

The paper's main objective is to get an understanding by exploring Poisson distributions, its applications, certain properties, distinct types of Poisson distributions, methods to explore the estimation of its parameter and finally the way it aids its users through its approximations. The conclusions that can be arrived at a broader sense is that it is certainly undeniable, that Poisson distribution has a greater width of applications in the future, be it the sports industry or the health care service industry where we had a glimpse of its usefulness. Use of Poisson distributions has also additionally benefitted the researchers in prediction of certain problems which can now be solved more accurately and deftly.

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Traceability Management System Using RFID in Vehicles for Parking: A Review

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Abstract: Using long range RFID enables users to gain access the easy way: a transponder or tag behind the windshield or otherwise attached to the car, is remotely read by a long range reader. Without any delay the barrier opens and the vehicle can pass through. Long Range Automatic Vehicle Identification Systems offers the highest level of convenience you can offer to your employees, suppliers and customers. AVI systems are designed to be connected to access control systems. The same systems you use for building access control, can also be extended to support vehicle access control which will enable you to extend the development of security policies. Time schedules and conditional authorizations can easily be implemented for vehicles.

Keywords: RFID (Radio Frequency Identification), AVI (Automatic Vehicle Identification), Transponders,

1. INTRODUCTION

Radio-frequency identification (RFID) is an automatic identification method, relying on Storing and remotely retrieving data using devices called RFID tags or transponders. The technology requires the cooperation of an RFID reader and an RFID tag. An RFID tag is an object that can be attached to an object for the purpose of identification and tracking. This can be done by using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader. An RFID tag is an object that can be incorporated into a product, here it is vehicles for the purpose of identification and tracking using radio waves.

Vehicle tracking has increased in use over the past few years and, based on current trends, this rise should continue. Tracking offers benefits to both private and public sector individuals, allowing for real-time visibility of vehicles and the ability to receive advanced information regarding legal existence and security status.

2. RELATED WORK

The present day metropolitan areas have seen a burgeoning growth in human population as well as vehicles. With shrinking spaces, operating a managed, busy and expensive parking lot having multiple gates can pose significant challenges, especially to a private organization that also owns some of the vehicles in the lot. The parking area has to be secure, with barrier-enforced entrances and exits. It also has to have an automated, efficient monitoring system that allows for accurate vehicle tracking as well as easy in-and out access for drivers.

With this RFID vehicle tracking system, vehicle information can be automated gathered to enable vehicle management to be more efficient and safe. With RFID vehicle tracking system with high identification accuracy, parking areas or gated communities can manage their vehicles efficiently without human intervention as well as easy in-and-out access for drivers and with low deployment and operation cost. RFID's also offers a turnkey solution for parking operators that require the ability to monitor and record not only access and exit to parking facilities but also log and bill back parking charges by customer.

3. COMPONENTS OF RFID

A basic RFID system consists of three components:

- i. An Antenna or coil
- ii. A transceiver (with decoder)
- iii. A transponder (RF tag) electronically programmed with unique information

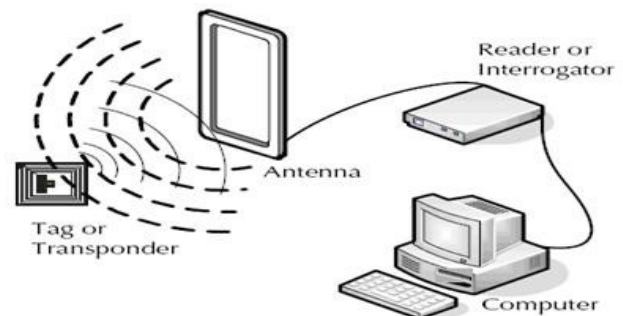


Fig. 1. Working of RFID System

3.1 ANTENNA

The antenna emits radio signals to activate the tag and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. Antennas are available in a variety of shapes and sizes; they can be built into a door frame to receive tag data from persons or things passing through the door, or mounted on an interstate tollbooth to monitor traffic passing by on a freeway. The electromagnetic field produced by an antenna can be constantly present when multiple tags are expected continually. If constant interrogation is not required, a sensor device can activate the field. Often the antenna is packaged with the transceiver and decoder to become a reader, which can be configured either as a handheld or a fixed mount device. The reader emits radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and the radio frequency used. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer for processing.

3.2 TAGS (Transponders)

An RFID tag is comprised of a microchip containing identifying information and an antenna that transmits this data wirelessly to a reader. At its most basic, the chip will contain a serialized identifier, or license plate number, that uniquely identifies that item, similar to the way many bar codes are used today. A key difference, however is that RFID tags have a higher data capacity than their bar code counterparts. This increases the options for the type of information that can be encoded on the tag. The amount of data storage on a tag can vary, ranging from 16 bits on the low end to as much as several thousand bits on the high end. Of course, the greater the storage capacity, the higher the price per tag. Like all wireless communications, there are a variety of frequencies or spectra through which RFID tags can communicate with readers. Low-frequency tags are cheaper than ultra-high-frequency (UHF) tags, use less power and are better able to penetrate non-metallic substances.

3.2.1 TYPES OF RFID TAGS

3.2.1.1 ACTIVE TAG

The active tags battery-powered and always well active. It is consistently on the lookout for a reader's signal.

3.2.1.2 PASSIVE TAGS

The passive tag relies on energy transferred from a reader to power up and transfer its information.

3.2.1.3 SEMI-PASSIVE TAGS

Semi-passive tags also use their battery to send radio waves to a RFID reader, where as these tags rely on the reader to supply power for its broadcasting.

3.2.2 FREQUENCY OF OPERATION

3.2.2.1 LOW FREQUENCY

Works on the principle of Inductive coupling. LF band ranges from 125 KHz to 134 KHz. This frequency band provides a short range of 10cm and has slower read speed than the higher frequencies, but is not very sensitive to radio wave interference.

3.2.2.2. HIGH FREQUENCY

Works on the principle of Inductive coupling. HF band ranges from 13.56. Frequency read ranges from 10cm to 1m. These systems experience moderate sensitivity to interference.

3.2.2.3. ULTRA HIGH FREQUENCY

Works on the principle of Electro Magnetic coupling. UHF band ranges from 860 MHz to 960 MHz Frequency range is up to 10m to 15m and UHF RFID has a faster data transfer rate than LF or HF and is the most sensitive to interference.

3.3 RFID Reader

A device used to communicate with RFID Tag. The reader has one or more antennas, which emits radio waves and receive signals back, from the RFID Tag. Also called Interrogator because it interrogates the RFID Tag. Data retrieval - RFID Reader – Device - Emits radio waves - Received by the RFID Tag - Activates the microchip data get transmitted.



Fig. 2. Vehicle with RFID tag approaching RFID reader

4. SOLUTION

A simple parking lot layout is shown in figure-3. When a vehicle with an RFID tag enters the parking lot, the RFID reader reads the tag and notes the in time and opens the barricade. As soon as the vehicle enters parking lot and approaches the reader at the entrance monitor inside the parking lot shows which parking lane is free so that the driver can park the car. Every parking lane in the parking lot must have a RFID reader to sense if a vehicle is parked in that lane or not, or every pillar must have a reader which reads number of tags in its oriented direction. That means it reads number of vehicles parked in the oriented direction. This gives information of the empty parking lanes for the new coming vehicles to park which is displayed in the monitor. At the exit as if RFID is linked with the prepaid accounts, charges for the parking will automatically be

debited from their accounts based on time parked. Barricades at the exit open when a vehicle approaches the reader at the exit. For payment we need an online site where

user can pay later without waiting in the queue at the .Using this online site users can also be given access to pre-book their parking lane for convenience.

CAR PARKING LAYOUT BLOCK A

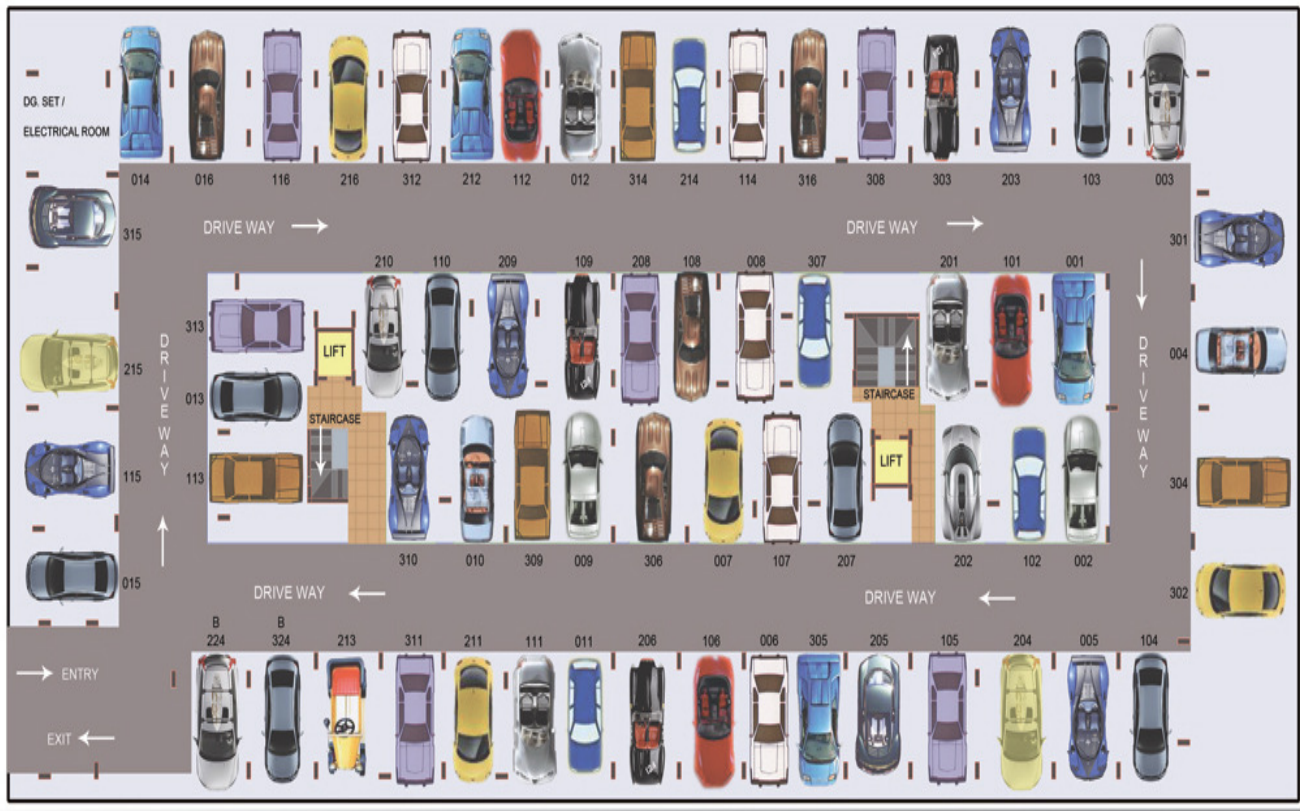


Fig. 3. Basic Parking lot layout

For this to happen we need many readers to read the tag on the vehicles, so there is a need for reduction of high priced RFID readers and make them economical for a firm to adopt this technology. Low frequency and high frequency tags can be used in parking lots, as very large frequency ranges are not suggested as they are not economical for day to day use.

5. CONCLUSION

RFID technology provides independent, non-stop tracking systems for security, parking, and access control. This technology provides businesses and communities with hands-free control to ensure only authorized vehicles have entry. RFID park lot management system is one of the few real-time locating systems that provide fast return of investment (ROI). System helped user reduce the time wasted in searching for parking place and also improve the parking lot utilization.

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Study on Small Scale Manufacturing Industries in India- Some Aspects of Size, Growth and Structure

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Abstract: The aim of this research paper is to study and analyze the problems faced by the the small-scale sector in India by the non-factory non-household segment of the manufacturing sector while working in global market. It is found to be a significant source of manufacturing employment. Small businesses often face a variety of problems related to their size. A frequent cause of bankruptcy is undercapitalization. This is often a result of poor planning rather than economic conditions. It is a common rule of thumb that the entrepreneur should have access to a sum of money at least equal to the projected revenue for the first year of business in addition to his anticipated expenses. A rigorous literature review has been done to identify the problems faced by Indian Small Scale Industries. The most important factor for economic development of a country is its industrialization. In India, Development is designed in such a way to remove poverty, unemployment and backwardness of the rural people. According to their nature, the problems have been classified into different sections like market problems, technological problems, production problems etc. Authors have observed that increased production cost and tough competition were among the biggest problems faced by Small Scale Industries. Finding of the current research can help the Indian SSIs in identifying the problems and make strategies to remove these problems.

Keywords: Small Scale Industries, Entrepreneurship, Production Problems, Market Problems, Employment Prospects

1. INTRODUCTION

Cottage and small-scale industrial sector plays a dominant role in the economic development of both developed and developing countries. A major objective of planned economic development has been industrialization and employment generation. In developing countries cottage and small-scale industries are especially important in context of employment opportunities, equitable distribution of national income, balanced regional growth and development of rural and semi urban areas. They provide immediate large-scale employment, offer a method of ensuring a more equitable distribution of the national income and facilitate effective mobilization of resources of capital and skill which might otherwise remain unutilized.

India is based on several culture and civilization. With the passage of time, India has been tremendously changed the whole scenario. Industry has played a crucial and pivotal role in developing nation and India to be digital which is the backbone of the nation. In Indian economy small-scale and cottage industries occupy an important place, because of their employment potential and their contribution to total industrial output and exports. Government of India has taken a number of steps to promote them. However, with the recent measures, small-scale and cottage industries facing both internal competition as well as external competition.

Small scale industries, including traditional cottage and village industries and modern small enterprises have been given an important place in India's economic planning for

ideological and economic reasons. Our late Prime Minister Mrs. Indira Gandhi once remarked, "Small scale industries offer many opportunities; besides adding to production, they broaden the industrial base. They enable the process of modernization as well as entrepreneurship to spread to more regions and layers of society".³ Father of our Nation, Mahatma Gandhi ji had strongly advocated the development of Indian villages by making them financially viable through small and village industrial units. The small scale and cottage industries also play an important role in removing regional disparities. The industrial development in a backward area can only be achieved by the rapid development and promotion of small scale industries. Besides economic aspects, the social role of small scale and cottage industrial units are quite significant in achieving various social goals such as removal of poverty, attainment of self-reliance, reduction in disparities in income, wealth and standard of living and regional imbalances..

According to the provision of Micro, Small and Medium Enterprise Development (MSMED) Act, 2006 the micro, small and medium enterprises are classified into two classes (a) Manufacturing Enterprises- The enterprise engaged in the manufacture or production of goods pertaining to any industry specified in the First Schedule to the Industries (Development and Regulation) Act, 1951. The manufacturing enterprises are defined in terms of investment in plant and machinery and Service Sector-

1) The enterprises engaged in producing or rendering of services and are defined in terms of investment in plant and

machinery. The limit for investment in small manufacturing enterprises is more than Rs. 25 lakh but does not exceed Rs. 5 crore and that of service enterprises is more than Rs. 10 lakh but does not exceed Rs. 2 crore.

Traditional small scale industries includes Khadi and Handloom, Handicraft, Village industries, Bamboo based industries, Sericulture and coir etc. Modern small scale industries produce a wide spectrum of goods ranging from comparatively simple items to sophisticated products such as television sets, electronic control system, mixer grinder and various engineering products particularly as ancillaries to the large industries. The traditional small industries are highly labor intensive, while the modern small scale units use highly sophisticated machinery and equipments

Programmes for modernization and upgrading of technology in the small scale sector to improve their competitive strength will be implemented. A new bank known as Small Industries Development Bank of India (SIDBI) has been established to channelize need based higher flow of credit, both by way of term loan and working capital to the tiny and rural industries. To help the artisans working with Khadi and Village Industries Commission (KVIC) and KVI Board, special Marketing organization at the Centre and State level shall be created. People are choosing any small scale and cottage industry without technical knowledge, its viability and profitability etc. Sometimes they succeed in getting loans from financial agencies to start a small scale or cottage industry. Loans received without knowledge of its proper and optimum utilization often leads to poor recovery by the lending agencies which also create problems in smooth functioning of these financial institutions. The present study aims to provide a concrete and proper ideas and information about all the factors discussed above. This work may prove to be the pathfinder to the new generation who are roaming here and their and chasing after jobs. This research would be of immense help to the common people, the policy makers, government officials, researchers and also to other non governmental organizations who are engaging themselves in the upliftment of the poor in particular and the socio economic development of INDIA as a whole.

2. LITERATURE REVIEW

A thorough review and survey of related literature forms an important part of research. It deals with the critical examination of various published and unpublished works related to the present study. Knowledge of related research enables the researcher to define the frontiers of his fields; it helps in comparing the efficiency of various procedures and instruments used⁴. Further review of literature avoids unintentional replication of previous studies and also places the researcher in a better position to appreciate the significance of his own results.

In the early literature on economic growth and development, industrialization as a source of employment and capital accumulation has been recognized by various economists. Here Ashish et al highlights the review of works.

For the first time, J.M. Keynes (1936) has focused his attention on the forces that determine employment policy followed in industrialization. He propounded the theory that entrepreneurs will offer the amount of employment which maximizes their output and profit.

According to Keynes “employment can only increase pari passu with an increase in investment”. W.A. Lewis (1954)⁶ has strongly advocated the application of labor intensive techniques of production to have a steady and smooth economic growth. He opined that many important works can be done by human labor with very little capital. Efficient labor could be used to make even capital goods without using any scarce factors. In this sense, small scale and cottage industry should be developed and promoted especially in an economy where capital is scarce.

Leibenstein and Galenson (1955) took an opposite stand and tried to show that labor intensive techniques might generate immediate output but little surplus since the wage bill would be large. Economic development preceded investment but the use of labor intensive a technique leaves little surplus for investment.

Dhar and Lydall (1961)¹⁰ made their study on the data collected from Census of Indian Manufactures, 1956 and the study prepared by the Perspective Planning Division of the Planning Commission in respect of capital, labor and output relations in various industries. They concluded that the issue of choice between large and small industries for the purpose of an employment-oriented industrialization strategy is largely irrelevant.

Professor Gunnar Myrdal (1968) recommends the adoption of a strategy based on predominantly laborintensive techniques in less developed countries on the ground that “the large volume of unutilized labor possessed by these countries has a productive potential, capable of creating capital and increasing production”.

According to the Village and Small scale Industries Committee Report (1955), popularly known as Karve Committee Report, since a substantial number of employed and underemployed belongs to the village and small industries group, setting up of small scale and village industries will provide employment to them in occupations in which they have been traditionally trained and for which they possess equipments.

3. HYPOTHESES

To meet the objectives of the study, the following hypotheses are postulated in the study:-

1. The area suffers from excessive and acute unemployment and under employment problem.
2. Persons suffering from underemployment are interested in taking up complementary jobs to uplift their level of living.
3. There is a lack of innovations and entrepreneurship in the state.

4. METHODOLOGY AND DATA BASE

In order to achieve the objectives our present study requires both primary and secondary data. Accordingly, a field survey has been conducted to obtain primary data adopting a sampling design of “two stage purposive sampling” with the selection of industries at the first and industrial units at the second stage. Information is obtained from the eight districts namely Bulendshaer, Alwar, Rewari, Hapur, Pilukhwa, Muradnagar, Amroha, Bahadugarh about the existing cottage and small scale industries.

In order to accomplish the objectives, the present study is mainly based on both primary and secondary sources of information. The secondary data is mainly congregated from published and unpublished works on the related topics. Census reports, economic surveys, journals, news papers, government and non government organizations (NGOs) associated with the industrial sector especially the Directorate of Industries, Directorate of Economics and Statistics, Directorate of Agriculture and Minor Irrigation.

Consequently, the final questionnaires were distributed among the owners, entrepreneurs or managers. Besides, unstructured interview and informal discussions were also held with the owners and workers SSI units. Due to the fact that majority of the SSI units in the state do not maintain proper account of their business, it was not possible to gather time series data on the variables like investment, employment and production etc. from primary sources. The information collected from primary and secondary sources has been edited, categorized and arranged in logical order.

The collected data so arranged has been examined with the help of appropriate statistical tools to draw the inherent facts. In analyzing data, simple statistical techniques such as percentage, comparisons, mean and coefficient of correlation has been used to deduce the association among variables, in order to reach conclusions.

5. RESULT AND ANALYSIS

Small scale and cottage industries are no doubt very important for the economy of the state in particular and the economy of India as whole. Recognizing the important role

that small scale industrial sector play in the national economy, both the central and state government have taken active steps to develop, promote and foster their growth. Some of these initiatives have been effective: but most of the problems of SSI still continue to afflict the sector.

6. ENTREPRENEURSHIP

- a) Entrepreneurship can be described as a creative and innovative response to the environment. such responses can take place in any field of social endeavour- business, agriculture, education, social work and the like.

Knowledge about the economic- political environment, more particularly about the economic policies of the government and the financial as well as commercial institutions, is important for the entrepreneur. An entrepreneur is a one who organizes, manages, and assumes the risks of an enterprise who visualizes a business, take bold steps to establish undertaking, coordinates the various factors of production and gives a start.

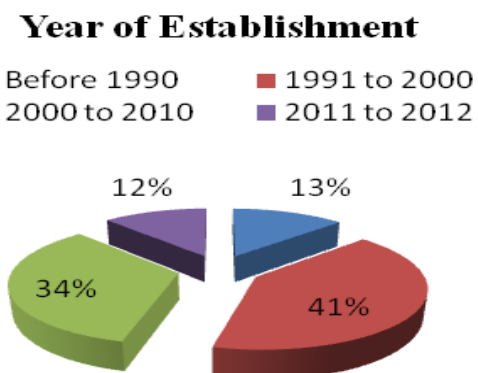
“Initiatives are underway to promote a culture of innovation based on entrepreneurship which can generate wealth and employment for all citizens.”

Skill India is Empowering workers to become employable. The National Skill Development Corporation(NSDC) is transforming the skill landscape. They drive economic growth and social development of a country. Nations with higher levels and better standards of skilled workforce are able to deal with challenges and opportunities in domestic and global markets.

6.1 GENERAL PROFILE OF ENTREPRENEURS

6.1.1 Year of establishment

The survey shows that majority of the small scale units i.e. 41% in the India were established between 1991 and 2000 followed by 34% in 2000 and 2010, 13% in 2011 and 2012 and 12% before 1990. A tremendous growth has been seen in recent years. Around 46% enterprises have started amongst chosen in last decade say after year 2000.

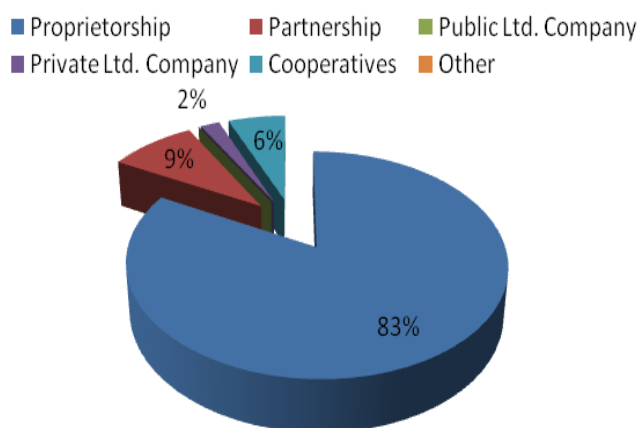


6.2.2 Types of Organization

There are various types of organization like individual proprietorship, Partnership, Public Limited Company and private Limited Company, cooperatives etc. are found in small scale industrial sector.

Sole proprietorship form of organization is the oldest and most common form of organization for small scale industries. 83% of the respondents owe proprietorship form of organization followed by partnership, cooperatives and Private Sector Company.

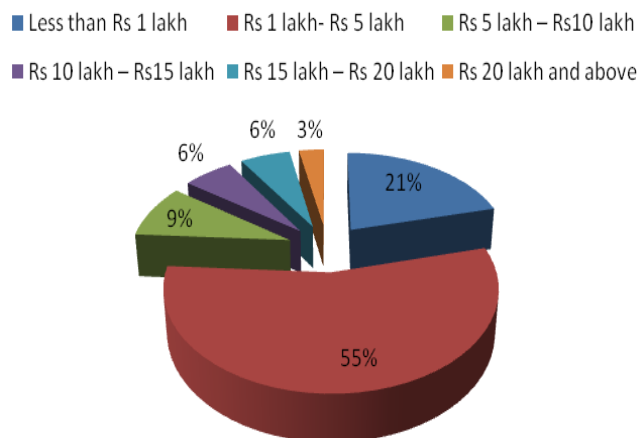
Types of Organization



6.3.3 Investment in Plant and machinery

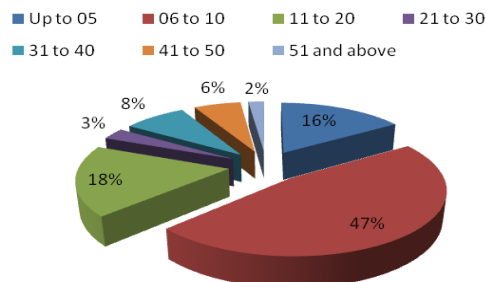
Investment in plant and machinery of an industry indicates its strength. Larger the industry, larger is the size of investment in plant and machinery. Majority of the sample small scale units are having investment in plant and machinery. 55% enterprises invested between 1 to 5 lakhs followed by 51% invested less than 1 lakh.

Investment in Plant and machinery



6.3.4 Size of Employment

Size of Employment

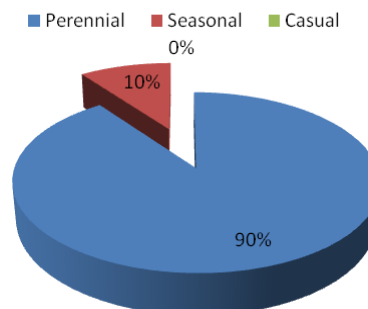


The number of persons working in an industrial concern indicates the overall strength and capacity of the industry. 47% enterprises have six to ten employees followed by 18% eleven to Twenty, 16% up to five, 8% thirty one to forty, 6% forty one to fifty, 3% twenty one to thirty and 2% fifty one and above.

6.3.5 Nature of Operation

Most of the small scale industrial units in the state are operating on perennial basis. Majority (90%) of the small scale industrial units are operating on perennial basis while 10 per cent are operating on seasonal basis. Ice Plants, Brick making units and units which depends on seasonal raw materials for their production like fruit juice units, gur making etc operates on seasonal basis. No casual units found operating within the sample units.

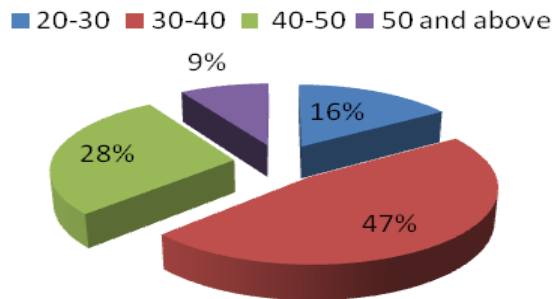
Nature of Operation



6.3.6 Age of Entrepreneur

The age of the entrepreneur plays an important role in the overall growth and expansion of any industrial concern. Innovative spirit, adoption of new methods and techniques of production, progressive outlook, risk taking ability etc. are very closely related to the age of the entrepreneur. 47% entrepreneurs are in the age group of 30 to 40 followed by 28% in the age group of 40 to 50, 16% in the age group of 20 to 30 and 9% in the age group of 50 and above.

Age of Entrepreneur



7. CONCLUSION

It is encouraging the development of SSIs sector as a way to diversify Indian economy. The main purpose of data collection was to study how the entrepreneurs managed the small scale industries and enterprises. What are the various problems faced by these enterprises. It also showed how the role of MSMEs helped in economic restructuring and development of India. Reorientation in the attitude of the people of the state in general, the educated youths and capitalist class in particular is the urgent requirement for paving the way of industrialization in India. People of the state must give up the lure to earn easy money and set their mind to take risk. They should learn from the past. We cannot deny that with “obsession over industrial revolution and liberalization.

This is not at all good for the country. If the small scale sector is to act as an agent of decentralization in rural and sub-urban areas, the government should come forward by making masses aware and strengthen the infrastructure in India. By Establishing more banks to provide loans to start or set up a small scale industrial units for their procurement and fulfillment of resources. Packages of incentives and the inherent talents of India in the form of a big push are required to move the economy on industrialization path and an empirical approach is needed to educate youth must come forward with a new vision and energy to break the vision of non industrialization in India.

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Investigation of Existing Hanger Making Process using Work Study

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Abstract: Method Study is the systematic recording and critical examination of existing and proposed ways of doing work so as to improve productivity. Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance. It provides the suitable recording technique to investigate information about existing process so as to improve it. The paper is about the method study and time study conducted at TRADC (Textile Research and Application Development centre), a unit of Grasim Industries Ltd. The main purpose of the study was to improve productivity by standardizing the hanger making process and its time. The study was carried out and improvements were implemented. After the implementation, there was significant time reduction by 23.08% and increase in operator's efficiency thus improving productivity.

Keywords: Efficiency, method study, time study, two handed process chart, workplace layout, productivity.

1. INTRODUCTION

Productivity improvement is the need of current industrial scenario. In industries or manufacturing firms the quantity to be produced is fixed and different techniques are used to improve process effectiveness and productivity. In R&D centers the quantity to be produced is not fixed and depends on the order from the customers. So, in order to improve productivity operator's efficiency is the area to be worked upon. In this paper a case study was carried out at TRADC (Textile Research Application Development Centre) to improve productivity. TRADC is a globally leading R&D centre of the Aditya Birla Group with 12 years of excellence having a vision to facilitate Indian Textile Industry for achieving global leadership by unleashing the power of innovative designs and products for rayon and its blend. Method study was carried at TRADC which in turn resulted with significant time reduction by 23.08% and increase in operator's efficiency by 17.073% thus improving productivity.

2. LITERATURE REVIEW

"Effective utilization of manpower in outside services for manufacturing firm", a case study discussed by **Ajinkya Jadhav**⁽¹⁾ which deals with the work study done using multiple activity chart and six sigma concepts which resulted in significant reduction of time and cost and helped improving operator's efficiency." A case study of productivity improvement by using IE tools", a paper pioneered by **Satish Keru Raut**⁽²⁾ deals with the different charting techniques used in the productivity improvement. It focuses about study being carried out at MAHINDRA for two operations for HINO on BMV 60. This resulted with

reduction in work content and increased operator's efficiency of doing the job." Application of Maynard Operation Sequence Technique – A case study", discussed by **Anuja Pandey**⁽³⁾ which deals with manpower efficiency improvement. The paper is about the improvement in the process effectiveness thus reducing work content and increasing productivity and reduction in operator's fatigue which in turn resulted with the increase in operator's efficiency. "Productivity Improvement by Work Study Technique: A Case on Leather Products Industry of Bangladesh", conferred by **Md.Abdul Moktadir**⁽⁴⁾ which deals with the study being carried out at leather industries. The work and method study as well as work measurement was done mainly focusing on the assembly line section and it resulted in the increase in productivity with the reduction work content by 12.7% thus benefiting the industry in terms of profit." An effort to apply work and time study techniques in a manufacturing unit for enhancing productivity", a paper presented by **Patange Vidyut Chandra**⁽⁵⁾ which is about the systematic approach towards the application of time study and method study. These techniques in turn decrease the work content thus improving the effectiveness and productivity of the process being done. The productivity is related to the work content which in turn deals with the reduction in ineffective time. Ineffective time can be defined as the time which is responsible for the increase in work content which may be due to the ineffective method or improper utilization of input materials and input resources. Ineffective time can be reduced using different techniques available to improve method effectiveness and operator's efficiency. This is

applicable for any manufacturing firm or industry or R&D centre.

3. METHODOLOGY

Based on the literature survey, the following methodology was developed to improve productivity:

- Systematic recording of all information about the existing process using suitable two handed process chart and multiple activity chart using method study.
- Critical examination of the process by questioning each fact that has recorded to develop alternatives and study the workplace.
- Evaluation of alternatives to select economic and easier method of doing work.
- Developing proposed method.
- Determination of standard time using stop-watch time study.
- Defining the final method.

4. CASE STUDY

The method study conducted in TRADC, there is opportunity for improvement in the garmenting department.

4.1 Garmenting Department:

The study was carried out on the hanger making procedure from readily available cut piece of fabric. It was found that the procedure so followed was tiresome for operators. The activity is recorded in the form of two handed process chart. The two-handed process chart is a process chart in which the activities of a worker's hands (or limbs) are recorded in their relationship to one another.

Existing workplace layout:



4.1.1 Two Handed Process Chart (existing):

Left hand activity	●	→	◻	▼	Right hand activity	●	→	◻	▼
Hanger taken					Idle				
Idle					Fabric taken				
Fold is opened					Fabric is inserted				
Stapler is taken					Hold the hanger				
Hold the hanger					Hanger is stapled				
Idle					Stapler is kept back				
Flip the hanger					Flattener taken				
Hold the hanger in flipped position					Stapled pins flattened				
Idle					Flattener kept back				
Idle					Cutter taken				
Hold					Strip removed				
Strip stuck					Strip stuck				
Hanger kept aside					Idle				
Idle					Cutter kept back				
Total	4	2	5	3	Total	5	6	2	1

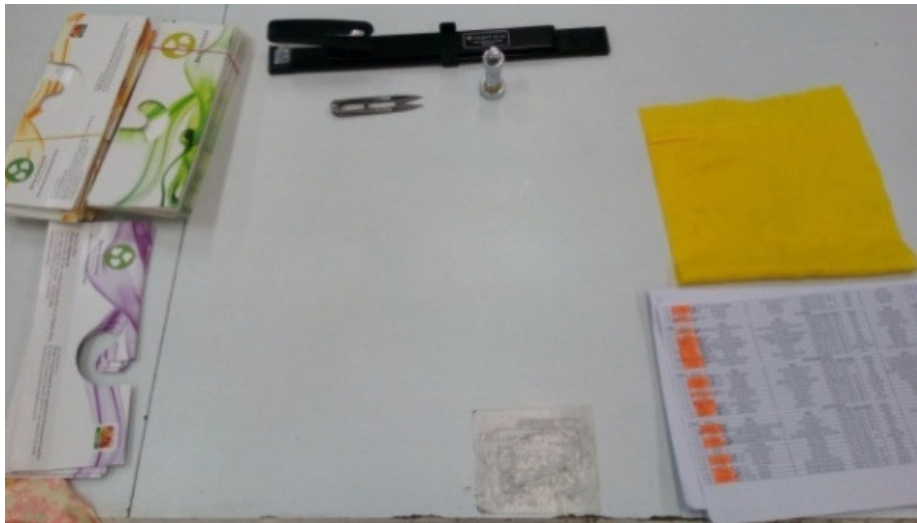
- **Summary:** Total process time for making single hanger = 67.6sec

Activity No.	LHS	RHS
● Operation	4	5
➔ Transport	2	6
■ Delay	5	2
▼ Hold	3	1
Total	14	14

Proposal:

A method with no delay was proposed to improve operator's efficiency. So the proposed method is:

Proposed workplace layout:



4.1.2 Two Handed Process Chart (proposed):

Left hand activity	●	➔	■	▼	Right hand activity	●	➔	■	▼
Hanger taken from stack	•				Fabric taken from stack	•			
Hanger brought to assembly		•			Fabric brought to assembly		•		
Fold is opened	•				Fabric is inserted	•			
Hold the hanger				•	Stapler brought to assembly			•	
Hanger inserted in stapler gap	•				Fabric stapled into hanger	•			
Hanger taken away from stapler gap	•				Stapler kept back & flattener is taken			•	
Hanger is flipped	•				Stapled pins flattened	•			
Cutter brought to assembly.		•			Flattener is kept back			•	
Hanger is held				•	Strip is removed by cutter	•			
Sticker pasted on staple pins	•				Sticker pasted on staple pins	•			
Hanger kept aside		•			Cutter kept back			•	
Total	6	3	0	2	Total	6	5	0	0

- Summary: Total process time for making single hanger = 52sec

Activity No.	LHS	RHS
● Operation	6	6
➔ Transport	2	5
■ Delay	0	0
▼ Hold	2	0
Total	11	11

- There was a decrease in time by 23.08% after implementation of proposed method.

4.2 Time Study:

Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance. Time study was conducted after standardizing the process to

calculate the standard time for the process. The readings were recorded in short time study form. The study was done for single qualified operator. The rating was given by the company personnel and accordingly standard time was calculated. The standard time was calculated using stop watch time study.

Conditions:

Operation – hanger making process

Worker – qualified

Rating – 75%

4.2.1 Time study sheet:

Operation: Hanger making Process						Study no. :1 Sheet no. :1		
Operator: Qualified						Studied By: Amruta Date: 20/06/2017		
Working Conditions: Adequate						Checked by : Mr. Ketan Patel		
No.	Element Description	Observed Time			Total O.T.	Avg. O.T.	Rating	Normal Time
		1	2	3				
1.	Hanger and fabric bought to working area and hanger is being opened.	7.57	10.5	8.67	26.74	8.91	75%	6.68
2.	Fabric inserted	14.5	16	15	45.5	15.16	75%	11.37
3.	Stapler bought to working area and hanger is being stapled.	18.5	18	17.1	53.6	17.87	75%	13.4
4.	Hanger is flipped, stapler is kept back and flattener bought to working area. Stapled pins are flattened.	8	9.56	10.3	27.86	9.29	75%	6.96
5.	Flattener is kept back and cutter is bought to working area and strip is being removed.	4.79	3.8	3.61	12.2	4.07	75%	3.05
6.	Sticker pasted on hanger and the cutter is kept back	3	3.01	2.78	8.79	2.93	75%	2.2
7.	Final hanger kept aside	3.66	3.41	3.51	10.58	3.53	75%	2.65
		Σ			184.72	61.76		46.31

Average Observed time = 61.76 sec

Normal time = Average Observed Time * Rating% = 61.76 * 0.75 = 46.31 sec

Allowances = Personal + contingency allowance = 4+6 = 10%

Standard time = Normal time * (1+ Allowances %) = 46.31 * (1+ 0.10) = 50.941 = 51 sec (approx.)

5. CONCLUSION

Method study is carried out in industries for productivity improvement and product optimization. Time study is carried to standardize process timing. However, from the above findings it can be said that method study and time study can also be applied in R&D centers as it deals with improvement in operator's efficiency of doing work thus reducing time and increasing productivity. So, with reduction in time by 23.08% and increase in operator's efficiency, the working process of R&D becomes more efficient which would help them for new product development.

6. RECCOMENDATIONS

After discussing and arriving at a conclusion the following suggestions could be drawn:

- Proposed workplace layout with tools & equipments pre-positioned.
- Significant reduction in time.
- Increase in operator's efficiency.
- No delay in job.

ACKNOWLEDGEMENT

We sincerely thank to the Head TRADC, Dr.Vijay Ramkrishnan and entire TRADC staff for their cooperation, motivation, and to enhance learning regarding the implementation of work study in R&D centers.

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Role of Industry Institute Interaction in Entrepreneurship Development

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Abstract: The paper aims to identify the requisite measures to be undertaken by an industry and institute in order to engage successfully in entrepreneurship development. The objective of any technical institution is to produce skilled and competent technical professionals through quality technical education and to prepare them for immediate employment in industries. However, with the globalization the past decade has seen a significant change in the requirements of industries. These new requirements demands, technical professional to identify and manage knowledge resources with business potential. Industry institute interaction (I-I-I) can provide best platform to engage industries with technical institute and I-I-I can have significant influence on development of technical students as a future entrepreneurs.

Keywords: Entrepreneurship, Industry, Institute and Students

1. INTRODUCTION

Technical education forms the backbone of progress of any nation. The journey of mutual aid between Industry and Institute has taken different forms at different times. Historically it started with simple interaction and gradually evolved to very close partnership overtime. India has one of the largest technical manpower in the world. But compared to its population, it is not significant and there is a tremendous scope of progress in this area. Bridging the skill gap is the need of the day and decides the national development and economic growth. Patil [1] focused on Industry-Institute Interaction benefits. Faculty members of the institutions should be aware of the various schemes from Government as well as other organizations for skill development and practical trainings. For countries like India, where huge man power resource is available, Institutions should come forward to take active part to grab this opportunity. Jayaprakash and Meenakshi [2] discusses on academic freedom in conducting Industry related research of commercial Entrepreneurs. Therefore Institute-Industry research partnerships should be redirected towards facilitating better research relationship for the welfare of mankind under academic autonomy. Lavanya [3] examine the different modes Industry –Academia Interaction adopted by the colleges and to analyze the student's awareness about the benefits from modes of Industry – Academia interface. By getting understanding in to these insights Academia can further develop the programmes which add more authenticity to the interface. Pai et al. [4] discusses the adoption and operation of curriculum which when taken up in professional colleges may help making of entrepreneurs when the student completes his academic courses. Richard and Gift [5] presented the survey which aimed at establishing the role of industry and commerce in

secondary teacher technical/vocational skills development through ODL.

2. INDUSTRY INSTITUTE INTERACTION

Interaction between industry and institute is increasingly a critical component of efficient innovation systems. Successful interaction between industry and institute supports the objectives of each partner. For institutes, typical objective to interact with industries includes improvement of teaching, development of advanced curriculum, reputation enhancement, and increase in placements. For industries, the motivation to collaborate with institutes includes gaining access to complementary technological knowledge, acquiring fresh talents through campus placements and providing training to existing or future employees.

Institutes are expected to broaden the experiential learning of students and develop the skill sets to match the current requirements of industries. To cope with these expectations institutes are engaging with all stakeholders which also includes industries.

3. CONCEPT OF ENTREPRENEURIAL INSTITUTE

There is empirical evidence that identifying, creating and commercializing intellectual property have become institutional objectives in various academic systems.¹ Technological institutes focusing on teaching, research and also economic development in form of entrepreneurship development. This shift in focus by institutes is majorly because of the influence of external environmental factors and internal factors both. External factor includes increasing competition in technological education sector and an internal factor includes self awareness of institutes towards need of harnessing potential of ecosystem.

Entrepreneurial institute concept focus on development of personal skill, attributes, behavioral and motivational capacities of students to facilitate application of these enterprising skills to start new venture or innovate in existing enterprises. Entrepreneurial institute not necessarily focus on setting up of profit organizations but equally applicable in the context of nonprofit organizations and social enterprises also.

However many academics and others view the entrepreneurial paradigm as a threat to the traditional integrity of the universities.² But it is evident from the examples of developed countries that role of technical institutes with entrepreneurial focus fosters technological innovation systems which leads to the path of economic development.

4. KEY CHALLENGES IN ENTREPRENEURSHIP DEVELOPMENT

Many technical institutes establishes entrepreneurship development (ED) cell with objective to help students in practicing entrepreneurship. Non premium and self funded technical institutes faces greater barriers in achieving the objectives of ED cells. Key challenges in development of entrepreneurship practice include

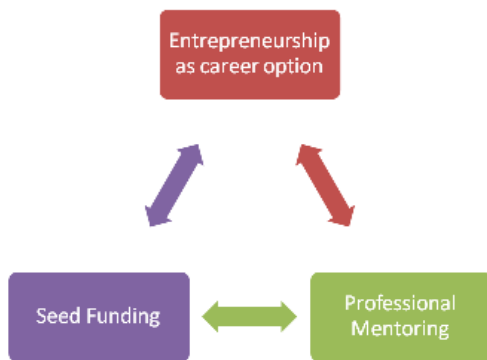


Fig. 1. Key challenge in ED

- 1) **Motivating students to take entrepreneurship as a career option:** The principal challenge before ED cells lies in motivating students to consider entrepreneurship as a career option and thereafter encouraging them to execute their business ideas in reality.
- 2) **Provision of good mentoring:** Another challenge lies in supporting students of enterprising mindset by a good mentor. Proper mentoring helps in smooth the progress of setting up startups and also facilitates networking with potential business partners and clients throughout the various phases of startups.
- 3) **Facilitation of timely seed funding:** Another main challenge in attaining goals of institute lies in

unavailability of seed funding for young students. Unlike developed countries, entrepreneurs in India face greater barriers in managing the seed fund for their business ideas because of less number of angel investors and venture capitalists are available in the country.

5. ROLE OF I-I-I IN ADDRESSING KEY CHALLENGES IN ED:

Engagement between industries and academia is critical for promotion of entrepreneurship among students. This engagement can expand the relevance of academic research carried out by students and faculties and foster commercialization of outcome of these research work. Developed countries are reaping the benefits from such engagements.

TABLE 1: Summary of I-I-I Measures to address key challenges in ED

Sr. No.	Key challenge	Measures by I-I-I
1	Lack of motivation to consider entrepreneurship as a career option	Training the trainers and implement entrepreneurial curricula
2	Unavailability of professional mentoring	Combining the experience of mentors with eagerness to thrive of students
3	Poor access to seed fund	Common commercialization of innovation through systemic approach

1) Training the trainer:

Industries can enhance the academic environment by addressing the barrier of lack of inspiration for students to practice entrepreneurship by motivating them through lectures or discussion sessions. Industries can also initiate the concept of training the trainers to build the capacity of teacher to inculcate the entrepreneurship skills among students. The collaborative relationship of industry and institute can spearhead the development and implementation of entrepreneurship curricula in the technical education sector.

2) Proper mentoring to start, restart and reduce failure stigma:

Students of this age are likely to have more ideas as they are to be considered as born digital and they are also taking advantages of increased learning opportunities available. Such students can be benefited a lot from well planned and implemented industrial mentoring programs. It is evident from the examples of Spanish universities that availability

of mentor can be a career impulse for students as it allowed them to seek personal guidance from mentor which can facilitate the smooth implementation of business projects. Positively build relationship between industrial mentor and academic student can address the challenge of networking for budding entrepreneur. Institute can foster the entrepreneurship by synergizing the entrepreneurial talent of students and professional guidance from industrial mentors.

Mentoring can increase the confidence and self esteem of students which minimizes the stigma surrounding the business failures and encourages the restarting.

3) Access to funding:

Industry and institute can take leadership role in promoting innovation by providing incentives that will encourage students to develop and apply competencies and skill set to exploit technology to create commercialized products and services.

Entrepreneurial development is about developing an innovation system but India is categorized in the group of countries having investment in R and D sector less than 1% of its GDP. Integration of research efforts to create intellectual property, innovative products and services is much weaker in India as compared to that of developed countries. This can be treated as opportunity by industry and institute to recognize the need of the holistic and systemic approach to formulating entrepreneurship financing policies. To attain the objective of sustainable development through entrepreneurship, timely availability of seed funding is critical.

Provision of innovation fund, technology transfer office and incubation centers can be instrumental in spurring early stage entrepreneurship through common commercialization of innovations between industry, institute and budding entrepreneurs.

6. CONCLUSION

The importance of entrepreneurship in the context of sustainable development through job creation, economic growth highlights the need for comprehensive framework

for the promotion of entrepreneurship development and calls upon the relevant organizations like industries and technical institutes in coordination of initiatives to facilitate entrepreneurship. Measures initiated by I-I-I can address the challenges related to fostering ED and facilitate systematic approach in attainment of goal of technical institute to develop students as a successful entrepreneur.

Industries and Institutes have been collaborating for over a century, but the rise of a global knowledge economy has intensified the need for strategic partnerships. The Institutes are imparting the basic knowledge and skill, but the Industry-Institute-Interaction will enable to undertake research by staff and students relevant to the Industry. The Industry-Institute-Interaction should be designed to run longer period for preparing the manpower of world class in the field of science and technology by inculcating the various skills required by the industry and thereby contributing to the economical and social development at large.

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Employee Welfare Activities- A Case Study of Hari Krishna Exports Pvt. Ltd.

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Abstract: Cutting and polishing diamond industry is a labour intensive industry, which is highly dependent on skilled labour force along with technologies. To increase productivity in such labour intensive industry one has to boost up worker's motivation. One way of facilitating motivation of workers is through labour welfare activities. This paper makes an attempt to study welfare measures and satisfaction level of diamond polishers towards employee welfare activities at the cutting and polishing units of Hari Krishna Exports Pvt. Ltd. As stated in to an Oxford Dictionary, welfare activities aim at making life worth living for worker. Labour welfare can be classified into statutory and non-statutory welfare measures. In this paper emphasis is given more on non-statutory welfare measures as it distinguishes the organization from other in terms of welfare measures adopted by it. For this purpose primary study of diamond polishers of the organization through a structured questionnaire and an in-depth interview of management has been done.

Key words: Employee Welfare, Employee Satisfaction, Diamond Industry.

1. INTRODUCTION

1.1 Employee Welfare

“Employee” or “Labour” is most crucial Factor of production, when it comes to make them work efficiently and effectively. Unlike other Factors of production, they have both mind and heart. To increase productivity of an organization, employees must be motivated to work with their heart and mind both. One way of facilitating motivation of workers is through employee welfare activities.

The Oxford Dictionary defines employee welfare as “efforts to make life worth living for worker.” While The [International Labour Organization] ILO at its Asian Regional Conference, defined labour welfare as a term which is understood to include such services, facilities and amenities as may be established in or in the vicinity of undertakings to enable the persons employed in them to perform their work in healthy, congenial surroundings and to provide them with amenities conducive to good health and high morale.

Moorthy (1968) has described two types of welfare in his book “Principles of labour welfare.” He has grouped welfare activities as welfare measures inside the work place and welfare measures outside the workplace. Welfare activities can be categorized as intra-mural facilities and extra-mural facilities. Intra-mural facilities include those facilities, which are provided within the factories while extra-mural facilities are those facilities, which are provided outside the factory. (Aswathappa)

It can also be classified as statutory and non-statutory activities. Statutory provisions are made mandatory by government by imposing laws such as, Factories act, 1948; The Mines Act, 1952 for the workers working in mines; the Plantation Labour act, 1951 for plantation workers; The Motor Transportation Workers Act, 1961 for motor transport workers; The Contract Labour (Regulation and Abolition) Act, 1970 for welfare and health measures of contract workers; The Merchant Shipping Act, 1958 that covers welfare measures of seamen. Dock Workers scheme, 1961 for the safety, health and welfare of workers working on the dock. Non-statutory benefits are those benefits that are done voluntarily by the company such as, loans for house, education of children, sports activities, entertainment activities, transportation facilities etc.

Employee Welfare Measures are justified because of some reasons. It helps in motivating employees, retaining employees, developing loyalty, minimizing social evils, improving company image, helps in cutting down labour turnover and makes employees happy, cheerful and confident looking. (Aswathappa) Employee Welfare Measures also improves efficiency, builds competitive advantage for the company, improves industrial relations, attracts more employees, urges employees to work better and induces them to work harder. (Reddy)

1.2 Hari Krishna Exports

Hari Krishna Exports, known as HK exports is a leading diamond manufacturing and exporting unit established in the year 1992 by Mr. Savaji Dholakia and his three brothers. The company is having two manufacturing units

in Surat where 5700 employees are working. One unit is at Simada gaam, varaccha, while the other unit is situated at Gems & Jewellery Park, Icchapore. Total turnover of the company has reached to 6000 crore rupees. Yearly production of the company is 10, 00, 000 carats diamonds. Company has business operations in more than 75 countries.

Mr. Dholakia who him self is not having education of primary schooling too; gives credit of success to his workers, whom he calls “diamond engineers.” He compares them with engineers as to cut and polish a diamond; they need to work very minutely with minimum mistakes as it a very precious commodity. The company follows highly employee-oriented philosophy. Here average salary of a diamond polisher is 58, 000 per month while average education is up to 10th standard only.

Savajibhai says, “we are not only giving salary but love to the employees.” He believes that by giving more, employees will feel accountable and will become more responsible. So by giving more the company is gaining more. He believes that in his factory he does not make diamonds but makes “Humans”.To concur his thoughts into the reality he personally looks into the welfare of the employees. Company spends 5% of the net profit on employee welfare activities every year. Some of the welfare Measures are so unique that it differentiates the organization from others into the industry such as distributing cars, homes or jewelry among employees as Diwali bonus. This made big news countrywide and it motivated the researcher to study other welfare measures provided by the company too.

2. REVIEW OF LITRETURE

Shivakumar (2008) has examined business practices of Jamshedji Tata with context to stake holder’s welfare. The article also examines employee welfare activities considered by Jamshedji Tata, which shows importance given to the welfare activities in nineties too.

The researches have been done in various industries for instance, Tiwari (2014) has studied employee welfare activies at Vindha telelinks Ltd. Jain and Goel (2014) have identified satisfaction level toward employee welfare activities in banking sector. Dr. Nair and Jha (2017) have studies employee welfare programmes in IT industry. Salaria & Salaria (2013) have studied welfare measures in auto sector. Ramya, Bhavashree and Dr. Lakshmi (2016) have studies welfare measured in hotel industry.

Qadeer and Roy (1989) have studied about the work, wealth and health of Indian workers in industrial sectors. A vast data was collected from the data published by the Labour Bureau of the Ministry of Labour and Employment, and information on industries of a district in Madhya Pradesh-Shahdol-and its surrounding areas and found that labour

unions had more concentrated on compensation and not on health and safety measures.

Jebamalairaja and pichumani (2012) have done research in this area on secondary database and have found that Labour welfare measures are grossly inadequate in India when compare to international standards. After visiting units of HK Exports it was clearly observed that the organization is not lacking behind in any terms where it comes to labour welfare.

Madhuri (1978) has studied in the article “Outlook on employee welfare cost” non-wage benefits from the view of management, Unions and employees in 16 manufacturing units of Mumbai.

3. OBJECTIVES OF THE STUDY

To study various statutory and non-statutory welfare measures adopted by HK exports Pvt. Ltd.

To study satisfaction level of diamond polishers towards these welfare measures.

4. RESEARCH METHODOLOGY

To study welfare measures and satisfaction level of employees towards employee welfare activities at Hari Krishna Exports Pvt. Ltd, secondary data was collected from the journals, articles, management books and websites. Primary data was collected through a structured questionnaire and in depth interviews with top management. Samplesize of 100 workers was selected through non-probability convenience sampling.

5. MAJOR FINDINGS

Statutory and Non-statutory welfare measuresat Hare Krishna Export Pvt. Ltd. and satisfaction level of workers towards it.

- At factory premises basic facilities are provided such as purified drinking water and toilets. 94 Percent employees are highly satisfied with drinking water facility. 66 Percent employees are highly satisfied with toilets while rests of employees think cleanliness should be improved regarding to the toilets.
- Canteen facilities are available where all 5700 employees take their lunch free of cost. 76 percent employees are highly satisfied with food and canteen facility while 20 percent are satisfied with it.
- Working hours are 9 hours a days including a lunch break. For this 88 Percent employees are highly satisfied, as they don’t need to do overtime except at Diwali time.
- Two paid vacations out of which summer vacation for 10 days and Diwali vacation for 20 days are given. Festival holidays are also given. 94 percent workers are highly satisfied regarding this.

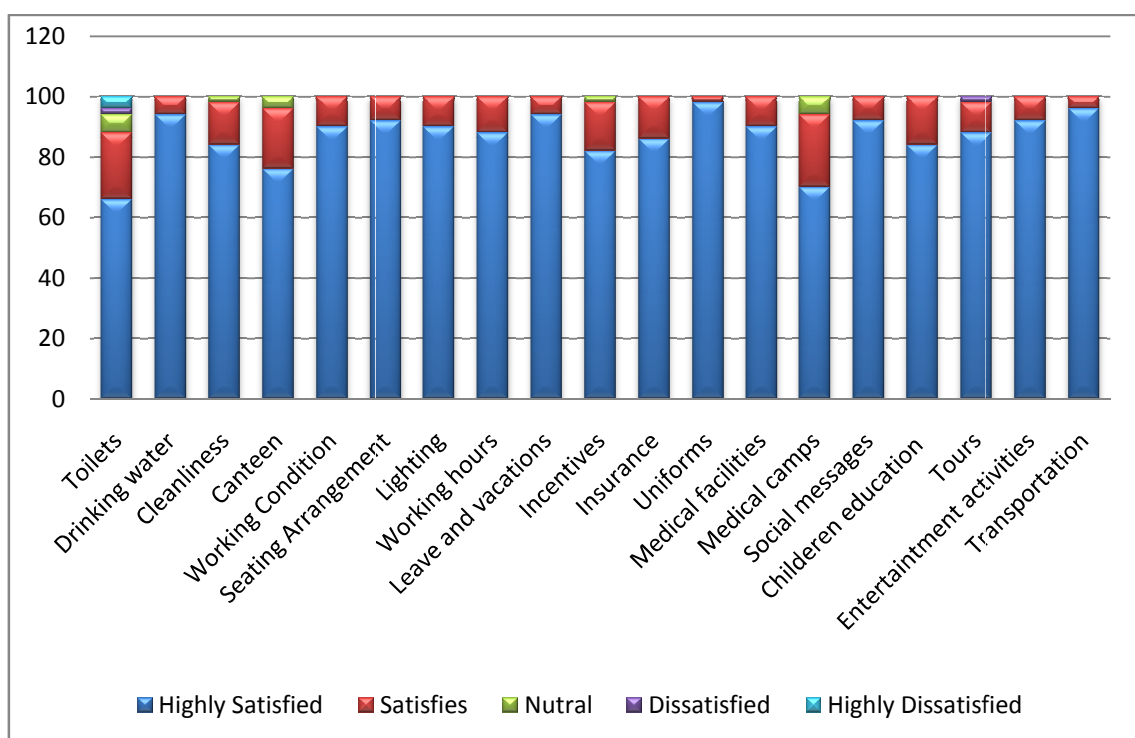


Fig. 1. Satisfaction level of employees towards various welfare measures at HK Exports Pvt. Ltd.

- Uniforms are distributed in adequate amount to all the employees. 98 percent employees are highly satisfied with adequacy of uniforms.
 - Transportation facility is available free of cost to the employees who wants to avail it. For that 96 percent employees are highly satisfied.
 - The work place is centrally air-conditioned with enough lighting and comfortable seating arrangements. Massage chairs are also available for employees who want to get relaxed during working hours. 90 percent with overall working condition, 92 percent with seating arrangements, 90 percent with proper lighting and 84 percent employees for overall working condition are highly satisfied.
 - Health and Safety measures
 - There is a clinic and an ambulance, which is available at the factory 24X7 for any emergency in case.
 - Every employee is insured against medical insurance. Employees with tenure of more than five years are having death insurance worth 10 Million INR.
 - Play grounds for out door games such as cricket, volleyball, swimming is there at company premises so that employees can maintain their physical health as well as they can get relax after work.
- Indoor games facilities are also available.
 - Company is having its gym where employees can come for exercising and can lead to a healthy life.
 - For mental health and relaxation the organization sends employees to 11 days workshop of “vipasyana”, that is meditation. Company bears all the expense of this program.
 - For the safety of employees it is compulsory to wear helmet while driving two-wheeler or they won’t be allowed to enter the company campus.
 - Strictly prohibition of chewing tobacco or smoking into the work premises or outside the work premises. This step has prevented many employees from the addiction of tobacco and smoking.
 - Company organizes blood donation camps and seminars on thalassemia and AIDS to spread awareness. Free compulsory check ups for the thalassemia are also conducted.
 - To encourage employees to take part in marathon company pays for those employees who volunteer

to be the part of marathon organized by local bodies. Around 4000 employees participate in this event.

- 90 percent employees are highly satisfied with basic medical facilities. For insurance 86 percent employees are highly satisfied. 92 percent employees are highly satisfied with social messages regarding tobacco and helmets. 70 percent employees are highly satisfied with medical camps and checkups. Here percentage is comparative law as being law in educational qualification they are not aware about the significance of these checkups.

➤ Educational facilities

- Employees: especially diamond polishers in the diamond industry are not much educated, but to make sure that their children gets education, company offers to pay fees for their children.
- For Gujarati medium, company pays yearly 3000 INR for nursery, 4000 INR for primary education, 5000 INR for secondary and higher secondary education and 6000 INR for graduation and post graduation.
- To encourage the employees to give their children education in English medium company pays yearly 7000 INR for nursery, 8000 INR for primary education, 9000 INR for secondary and higher secondary education and 10, 000 INR for graduation and post graduation.
- More ever, notebooks are also distributed to the children of employees.
- Various seminars on parenting and childcare also conducted by the organization for awareness.
- 84 percent employees are highly satisfied with these educational facilities.

➤ Recreational facilities

- The company organizes religious tours every year for employees and for their parents, once in every 3 years.
- The company for the entertainment of the employees also organizes various cultural programs such as shows for plays, Navratri functions, and movie days.
- To motivate employees slogans and inspirational thoughts are written on the walls in local language.

- 88 percent employees are highly satisfied with the facilities they enjoyed on tours and 92 percent for other recreational facilities such as entertainment facilities.

➤ One Step ahead

The organization also does some unique welfare activities that are rare.

- HK diamonds distributes houses, cars and diamond jewelry to the workers as Diwali bonus according to their set standards of performance. Up till now 2900 workers are benefited from this scheme. The bonus is given as per their performance against set standards. The company does fulfillment of down payment or EMIs as per the requirement and performance of the employees. On inquiring about would they prefer cash to these benefits; they replied that they are being paid enough salary so these kinds of benefits are more useful to them. The organization distributes cars or houses or jewelry as per the necessity of the workers. Mr. Dholakia is having a dream that every employee should have all these facilities when he retires from the organization.
- They also arrange for weddings of the sons and daughters of employees, where company bears whole cost of wedding. In 2014-30, in 2015-66 and in 2016-53 such marriages were organized and sponsored by the company.

6. CONCLUSION

Employee welfare measures are vital to any organization as this leads to many benefits to the organization. Welfare Measures that are imposed by the Law are Statutory Welfare Measures. But when it comes to Non-statutory Welfare Measures, it is totally up to the culture of the organization and philosophy of the management. As research has demonstrated, the organizational culture of Hare Krishna Pvt. Ltd. is "Employee Oriented." Some of the welfare measures such as distribution of bonus at the time of Diwali, funding weddings of the children of employees, religious tours for parents of the employees are unique; as these activities are not only for the employees but also for their families too. Here the satisfaction level of employees towards welfare measures is very high. The organization truly provides an inspirational model to other organizations for Employee Welfare Measures.

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Environmental Impact of Tourism on Vembanad Lake

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Abstract: Vembanad wetland is the largest wetland system in India which is the official site of the Ramsar convention on Wetlands. Human intervention on the lake is severe which affects the function, structure and entire composition of the Vembanad wetland system. There is a drastic growth in tourism sector in and around Vembanadu Lake for the past two decades. This paper focuses on the impact of tourism on Vembanad lake system and also to the environment. As a result of the tremendous growth of Backwater tourism in and around the Vembanad Lake, the waste composition has increased to a large extent. The major waste from tourism sector was identified through a questionnaire survey, on the peoples residing near the lake and these waste were quantified through different methods. The performance evaluation of the existing waste management system was conducted and found to be ineffective. Since a lack of a proper waste management system, this paper aims to propose a modified waste management system which is economically and socially beneficial. The economic analysis was done by conducting cost benefit analysis to the 4 alternatives and the existing system. These four alternatives were designed within the framework of the modified waste management system. The payback period of these alternatives and existing model were calculated and based on this, the most economical and social waste management system was proposed

Keywords: backwater tourism, performance evaluation, waste management, cost benefit analysis, paybackperiod

1. INTRODUCTION

Vembanadu Lake spreads in Alappuzha, Kottayam and Ernakulum districts of Kerala which forms Vembanad Lake wetland system of an area of 2033.02km². In the past twenty years the growth of tourism sector in and around the Vembanad Lake is spectacular. Backwater tourism as emerged as the backbone of the tourism sector of Kerala state which leads to the tremendous increase of Houseboats in addition to many resorts which developed recently around the shore of lake. Kerala comes under the list of 50 places of Life time published by National Geographic Traveler scenic beauty of the region attracts the domestic as well as the foreign tourists. Kuttanad wetland system including Vembanad Lake which is now receiving global attention because of its unique feature which is below sea level permits the cropping of Rice in large quantity and permits the harvest of fish and an area which is thriving for the tourism where the nature beauty is at the peak among the Ramsar site.

Percentage of increase of foreign exchange earnings from tourism in Kerala in last decade is 68.9%. Rise of tourism sector results into shift of employment, one or two member from each house is now engaged in tourism industry as houseboat operators or other employment related to house boat and backwater tourism. This shift in employment sector from agricultural to the service sector is caused as a result of change in attitude and perception to the traditional occupation like agriculture. Shift of employment itself indirectly effects the agricultural production of the region. Uncontrolled growth in the number of the houseboat in Vembanadu wetland system affects the environment system

of lake. This project focuses on the adverse effect of the backwater tourism growth on the environment system of wetland and livelihood of the area around the lake and to find out a proper waste management system in the region.

2. LITERATURE REVIEW

There has been an ample amount of literature in the domains of tourism and its causative factors from various studies conducted around the globe. Many of them are based on different aspects. By looking through the literature in environmental impact of tourism the commonality observed in the existing literature is that tourism can affect Socio-cultural of host community which includes changes in traditional lifestyles, value systems, family relationships, individual behavior and community structure. Even though the tourism sector in the region has greater economic benefits which are employment income and foreign generations there are also negative socioenvironmental impacts (Zacharias and Manalel, 2010). Tourism development can be of benefit (e.g., job creation, image enhancement). However, it could also have negative impacts on the biophysical environment (e.g., soil pollution, water pollution, air pollution, ecosystem degradation) and social/cultural environment (e.g., loss of the traditional culture, increase in crime) if not well planned, developed, and managed (Mohammad, 2016). In another one the impacts of tourism on environmental attributes such coral reefs, water, fisheries and beaches are discussed briefly. The impacts of tourism towards environmental attributes range derives from tourism activities such as boating, snorkeling, diving and fishing. Improper and irresponsible behavior of tourist is also believed to be a significant reason

that contributes to detrimental effects on the environmental attributes (Murugadas and Badaruddin, 2014). The different mind-set of tourist derives from the different level of environmental literacy that they have. The concept environmental literacy that consists of not only knowledge on the environment and its issues but also includes disposition components of attitudes, sensitivity and motivation are discussed thoroughly. Intention to act or intended behaviour that is explored in this (Ferry, Lucky, Dietrich and LilikBudi, 2016). The link between the number of threatened plant species and tourism which was proxies by the number of international tourist arrivals (Muzafar and Radamd, 2016),). Tourism has been an important sector to both the developed and the developing economies. Although we recognized the great benefits of the tourism sector to the national income, the tourism activities have also been connected to the negative impact on the economy in particular to the environment. One crucial aspect of the negative impact as a result of increased tourism activities are on the loss of biodiversity. Tourism has an adverse effect on the environment in Eastern EU. Finally, short-run heterogeneous panel causality test results suggest that tourism, causes CO₂ emissions in Eastern EU while economic growth and CO₂ emissions cause tourism in Western EU. Overall, findings suggest that tourism plays an important role in accelerating economic growth however; its role on CO₂ emissions largely depends on the adaptation of sustainable tourism policies and efficient management (Alexandra, Christos, Nicolas, Dimitra, 2015).

On the other hand, protected riverside area can make rivers as a source of water, water transport and water tourism destination. Nowadays, water tourism is increasingly popular to people. Local residents should be given an understanding of the importance of tourism activities mainly based on the river environment and things that need to be done to support these activities. River cleanliness must be maintained and preserved (Tri Rahayuningsiha. Hariri and Lilik, 2016) Another one puts forward a generic methodological scheme, based on Life Cycle Assessment (LCA) principles, in order to estimate the environmental load in areas of considerable tourism activity. A comparative assessment is realized for characteristic hotel categories. Their respective contribution to environmental burden attributed to tourists' transport and accommodation services is assessed. Up-market hotels impose larger absolute impacts on the environment, especially in the consumption of resources. LCA can play a crucial role in decreasing the complexity in the strategic planning of tourism, especially in local-to-regional areas of concentrated tourism activities (Orkut and Murat, 2014) Tourism is being considered as a development instrument in order to boost a country's economy and has become part of the global industry. However, tourism is also one of the actors that is responsible for environmental depletion, due

to the constructions of buildings and tourism activities(Hsin and Shiann, 2013)

3. METHODOLOGY

Research is a process of arriving at an appropriate solution to a problem through a systematic approach. This systematic approach will be obtained through a well-defined research methodology. In this project the methodology involves three phases. In phase-1, the problem was identified through a clear background study. After the problem identification a detailed literature survey is a need to define the problem. From the problem definition, the main objectives of the project were determined. As the first step the different types of waste generated from tourism, that affect the Vembanadu Lake was identified. In phase -2 the major waste from the generated waste should be identified. For this a questionnaire survey was conducted and the data was collected from the people residing near the shores of the Vembanadu Lake. In this phase the most predominant waste was determined and was estimated. In phase -3 the existing waste management for the major waste was studied and the performance evaluation was conducted. Based on the evaluation, modification was done to the existing waste management system. Different alternatives were identified and conducted a cost benefit analysis, to find out the best alternative in the waste management

4. RESULTS AND DISCUSSIONS

Rapid increase in house boats, hotels and resorts due to the fast growing back water tourism in Vembanadu Lake causes a tremendous increase in waste generation. Hence there is a lack effective of waste management system in Kumarakom. The main objectives were to identify and estimate the amount of major waste generated from tourism which affects the Vembanad Lake, to conduct a performance evaluation of the existing waste management system and to modify the existing system and conduct cost benefit analysis.

4.1 Questionnaire Survey

A questionnaire survey was conducted as part of the study to understand the major waste from the listed ones and to evaluate about the existing waste management system. The questionnaire consists of 29 questions, out of which first 27 questions were using five scale and these questions were used to measure the effects of each waste components. 28 and 29 were used for rating the waste components for identifying the major waste. The survey was done with the people residing near Vembanadu Lake. Major waste generated from tourism was identified. Survey was conducted with 180 people residing in a stretch of 30km length and a width of 2km from the lake. The sampling technique used is area surveying. 3 respondents from 1Km² area are selected. The number of household units who

participated in the survey was 180. The respondents were approached individually at their homes to get their responses [3]. The major findings from the survey include different negative impacts of tourism and focus on the waste generation. By the help of this survey, it has being identified that sewage from house boats, resorts and hotels and plastic waste dumped in boat jetties and small tourist spot are the major waste from tourism.

4.2 Quantification Of Major Waste

The major waste from tourism is found to be sewage and plastic waste from houseboats, resorts and hotels. The quantity of waste generated from tourism is identified. The unavailability of pre-determined data of amount sewage and plastic generated was a limitation. So the quantification was a big task. The average estimation of waste generated was calculated by conducting a survey and field visits. Sewage from house boat is treated at DTPC sewage treatment plant and the sewage from resorts and the hotels is treated in their own plant. The quantity of sewage treated from house boats was obtained from DTPC sewage treatment log book, but the amount treated in resorts and hotels was not obtained, because they won't keep any records. Estimation of sewage is given below. Kumarakom, 103 registered house boats are there, as per the records given by the DTPC. The maximum amount of sewage is treated at the months of December and

January. From the data an average of 65, 520 litre of sewage is treated in every month.

To identify the amount of plastic waste generated in a month we conducted a survey and field visit to selected tourist spot. The survey was conducted for five consecutive days, at three times a day to get the exact amount of plastic items are dumped in six different spots. Table I shows the mean of the amount of plastic waste generated from the six tourist spot in Kumarakom, for five consecutive days. The plastic waste we are considering are drinking water bottles, soft drink bottles, ice cream cups, plastic glass, are the main plastic waste in these tourist spot.

From the survey the amount of plastic waste generated from hotels and resorts was calculated. In a month approximately 4, 665 kg of plastic is generated from the hotels and resorts in Kumarakom. It's just an approximate amount, this can vary on seasons. From the 21 resorts and hotels these quantities of plastic waste is generated. In this we are considering only on drinking water bottles of 1 litre and ½ litre. In addition to these many other type of plastic waste can be generated such as ice-cream cups, plastic bags, and soft drink bottles so on. This waste can't be estimated due practical difficulties. Annually the least amount of plastic generated will be 55, 985 kg from hotels and resorts

TABLE 1: Quantity of main plastic waste generated at different tourist spot

Sources	Unit	Wt./No.	Mean Total(No:s)	Mean Wgt(Kg)
Water Bottles	No.s	27.98	112.2	3.13
Soft drink bottles	No.s	30.25	94.8	2.86
Ice-cream cups	No.s	5.97	73	0.435

4.3 Performance Evaluation Of The Existing Waste Management System

The major waste from tourism are found to be sewage and plastic waste from houseboats, resorts and hotels. The present system of waste management in Kumarakom is not very efficient. The only way of treatment is done for sewage. The sewage from the hotels are treated in their own treatment plants. Most of the resorts and hotels have treatment plant. The sewage from house boats are treated in sewage treatment plant in DTPC, from the data obtained it is also ineffective. Out of the 103 registered house boats, only 70 of them is undergoing sewage treatment from the plant at DTPC. They are charging a minimum amount of Rs.1250/- monthly from these house boats. The existing system has a cash inflow of Rs.1, 26, 500/- and has a payback period of 10.5 years. In the case of plastic waste there is no proper segregation from the panchayat or from the DTPC Kumarakom. The plastic waste are simply dumped in open spaces and also near the shore of the Vembanadu Lake. These waste are collected by some

unauthorized people daily. There are a limited number of waste bins are situated at different locations. Most of these plastic waste are dumped in open spaces.

The performance of the waste management system in Kumarakom was also evaluated in the questionnaire survey. The questionnaire survey also consists of questions about the management of waste and the satisfaction of people towards the waste management. Out of 180 respondents, 73% of the respondents say that sewage treatment is ineffective and also 67.2% strongly agree that waste management system in Kumarakom is no properly managed. 69 %of respondents stated that cleaning is very important because their no collection or segregation process is taking place.

4.4 Modification of the Existing Waste Management System

The present waste management system in kumarakom has to be modified. From the performance evaluation of the

existing system there should be proper way of collection and segregation of the waste. Sewage from house boats should be collected by some water transport and some fees should be collected from the house boats for treating the sewage, since most of the hotels have sewage treatment plant their isn't necessity of collecting sewage from the resorts and hotels .Since there isn't a proper management of plastic waste, the collection and segregation is also important .the establishment of collection bins at different spots are important for collection. These waste are should be collected by worker and to be segregated in a collection center and to be sold to get some benefit. This system has social benefit than economic benefit. The modified waste management system focuses only on two pre-dominant waste i.e. Plastic and sewage.by the questionnaire survey it has being already stated. he above frame work is used for modifying the existing waste management system. Here the

sewage from the resorts, hotels and house boats are collected and then transported to the treatment plant. The treated sewage is flowed out to the Vembanadu Lake. Similarly the plastic waste from resorts, hotels and from other tourist spot should be collected accordingly and transported and segregated at suitable collection centre. This frame work will help to reduce the effects of plastics and sewage. Within this frame work we implementing four models. Since this is a social issue, it has more social benefit than economic benefit. In this project we are dealing with four alternatives models from this frame work. For deciding the best alternatives we are conducting a cost benefit analysis for each alternatives. These alternatives will be made from this frame work. The implementation of this modified waste management system has both social and economic benefit.

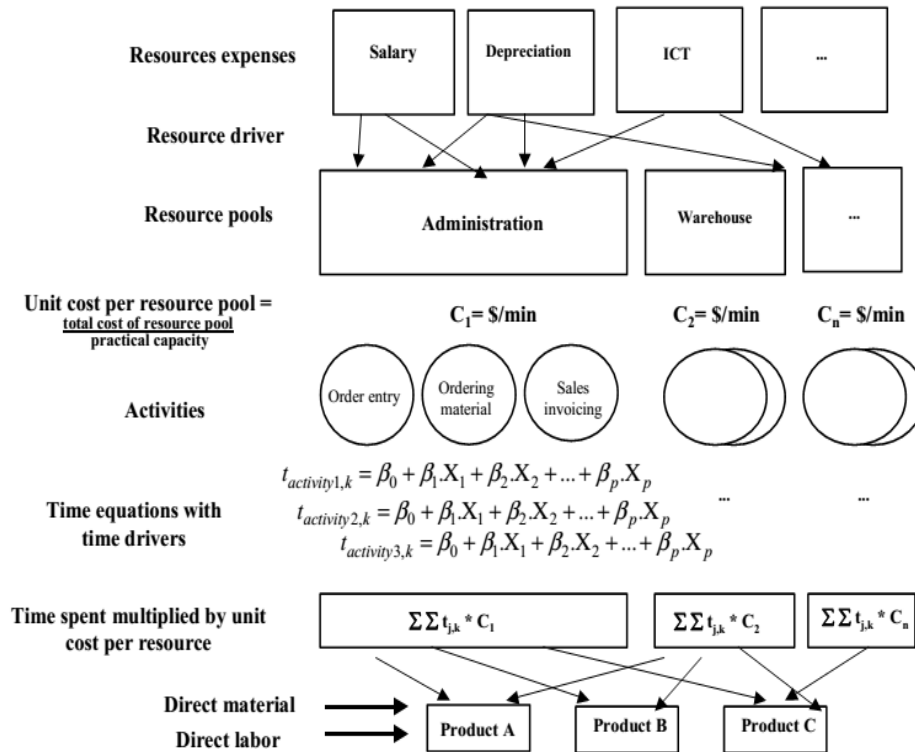


Fig. 1. Modified Frame work of the waste managemen System

4.5 Pay Back Period

The payback period can be calculated. For computing the payback period the fixed investment required for every model and cash flows from that model have to be calculated. For calculating fixed cost of alternative models the expenses related to machinery and other pre-operative expenses are estimated. Next step was to calculate the variable costs associated with different models. This calculation not only helps in DPP but also it will provide an

idea about working capital requirements. Here the variable costs involves, labor payments, utilities paymentsand maintenance costs.After calculating the variable costs the total revenue that can be obtained from the models are calculated considering the price of outputs from the model. This total revenue is subtracted with current revenue to find out the additional revenue obtained from the models. Additional revenue is further subtracted with variable cost to calculate the additional cash inflow per year for a models.

TABLE 2: Cost Benefit Analysis for Different alternatives

Model	A	B	C	D	E
Existing model	13, 30, 000	9, 23, 500	10, 50, 000	1, 26, 500	10.5
Alternative-1	Nil	Nil	Nil	Nil	Nil
Alternative -2	28, 46, 000	29, 16, 900	34, 51, 102	5, 34, 112	5.5
Alternative -3	38, 31, 000	33, 12, 900	28, 39, 893	Nil	infinite
Alternative-4	37, 15, 500	29, 96, 000	31, 42, 102	5, 46, 012	7.5

A-Total Fixed investment B-Variable cost per year C- Total revenue
D-Cash inflow E- Payback Period

Mathematically Fixed cost (A) = cost of machinery + installation charges Variable cost (B) = labor payments+ utilities payments+ maintenance costs Total revenue(C) = Sum of revenues obtained from all output products from the alternative Cash inflow per year (D) = Total revenue – Variable cost Pay Back Period (E) = Fixed Cost/Cash inflow All of these parameters for different models are calculated and the results are as shown in table –II. By conducting the cost benefit analysis for each alternative, the best alternative was found to be the second alternative.in this case the payback period was found to be 5.5 years. In these alternatives the sewage is not collected but these are directly treated from transporting the sewage from the house boat to the tank. In this the number of house boat treated should be noted, the first and the third alternative can't be implement because the total variable cost is more than the total revenue. The fourth alternative has a payback period of 7.5 years. In this alternative the collection is done properly as compared to the fourth alternatives. For an effective waste management the fourth alternative will be selected, because it provides both social and economic benefits. When compared to existing model, collection of sewage and plastic waste was not done.

5. CONCLUSION

Even though the tourism sector in the region has greater economic benefits which are employment income and foreign generations there are also negative socio-environmental impacts. To understand these impacts to the environment of the Vembanadu Lake and to find an action plan is a need to the society. To understand these impacts a questionnaire survey can be done. For this a questionnaire was developed on the basis of the sources which affect the environment. The predominant waste from tourism were identified through detailed literature survey, field visits and also by conducting a questionnaire survey. By studying the existing waste management system in Kumarakom, it was found to be in efficient. A modified system was proposed for the proper management of waste. A frame work was suggested for this purpose, which mainly include collection and transportation. Within this frame work four different

alternatives were made. The four alternatives were proposed, on looking forward the social and economic benefit of these different system to the environment and to the society. The decision of finding the best alternative was done, by conducting cost benefit analysis.Since this is a social issue we have certain limitations for making the profit.

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Response Spectrum Analysis for Optimized Building Configuration on Hills in Severe Seismic Zone

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Abstract: Improvement in tourist places contributes to the economical growth of country especially northern region in India which is the most visited tourist places in Himachal Pradesh lies in seismic zone IV and V. Development of those regions impact majorly on overall attraction of tourists. But due to topography of India, northern region is covered with mountains and due to developing cities and urbanization with increase in population construction are carried out on hills. This makes structure unsymmetrical due to slope of ground. This paper studies the dynamic response of step back building with different configuration provided with set back and various bracing system to different heights of building in terms of storey drift, base shear and fundamental time period. All sixteen models are analyzed for dynamic analysis by response spectrum method in structural STAAD Pro. software. The performed analysis conclude with the optimized building configuration on hill slope.

Keywords: Step back building, storey drift, base shear, fundamental time period, optimized building configuration.

1. INTRODUCTION

Development of desired place in Himalayan region of country contributes to originate the economy of such regions due to influx of tourists along with rapid urbanization and highly increase in population. However, due to scarcity of flat terrain or plain lands in hilly areas, buildings are constructed on hills or sloping grounds in those regions. Structural performance of buildings on hills is different than buildings on plain ground. Buildings on slopes are generally constructed as Step back buildings and can be combination of step back and set back buildings. Structures on slope are unsymmetrical which develops torsional moments in structures and cannot resist lateral forces due to eccentricity caused by difference in center of mass and stiffness of each floor. Earthquake forces are lateral forces and the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0. During such high intensity earthquakes, step back buildings attracts more lateral force towards the short column and due to torsional moments, short column fails first and structural stability of building gets disturbed.

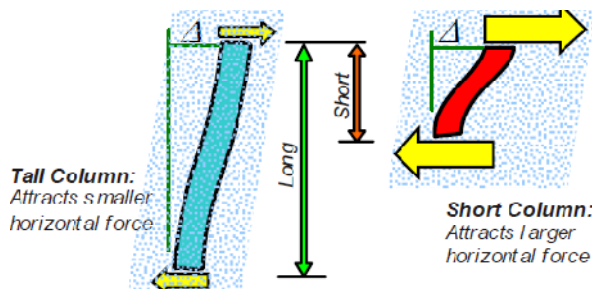


Fig. 1. Short column effect

To improve the performance of such buildings on hills or on slope many researches were carried out. Birajdar and Nalawade performed analysis on 24 building models of three configurations by response spectrum method and incorporate that the failure occurs in buildings on slope as a result of short column effect. Zaid Mohammad et.al studied different configuration of step back building and step back & set back building and suggest most suitable configuration for buildings on slope in earthquake prone areas. Nagargoje and Sable presented seismic analysis on step back building, Step back and set back building and set back building. The work shows the comparative study of three configuration with respect to the parameters as base shear, top storey displacement, store drift etc. Kalsulkar and Rathod analyzed the building of step back frames and step back-set back frames on various sloping ground for zone III. This study states, step back-set back frames gives least values of time period and base shear, the performance of step back frames proves more vulnerable than step back-set back frames and suggested for special attention while designing short columns. Y. Singh et.al highlighted on seismic behavior of hill building during the Sikkim earthquake of September 18, 2011. Analytical investigation carried out to know dynamic response of hill buildings comparing with regular buildings on flat ground in terms of fundamental time period of vibration, inter-storey drift, column shear etc. Hirde & Shelar and Junghare & Shinde studied on positioning of RC shear walls and bracing system for seismic analysis on buildings resting on sloping ground. Represents results in terms of parameters as base shear, lateral displacement, time period and member forces.

Many analysis are carried out to study the performance of structures on slope. To improve performance of step back

buildings during earthquake various configurations can be adopted. Provision of Set backs in step back building can gives optimized building configuration. Step back buildings can also be incorporated with the lateral load resisting members as different bracing systems or shear walls at different locations. And dynamic analysis by response spectrum method can be carried out according to IS 1893-2002 (Part 1) to know the performance of those building during earthquake.

2. ANALYSIS METHOD

Dynamic analysis by response spectrum method is performed on three dimensional model according to IS 1893-2002 (Part 1) on RCC structure, by assuming concrete as homogeneous, isotropic and elastic material with modulus of elasticity as 21.718 KN/mm^2 and Poisson's ratio as 0.17. Three dimensional models of step back buildings are generated with fixed support at foundation and analyzed for dynamic analysis in structural software STAAD Pro.

2.1 Geometrical parameters:

All building configurations are resting on ground of slope 15° and three different storey buildings as 10 storey, 8 storey and 6 storey with same plan has considered to perform analysis. Dimension of building in X and Z direction is symmetrical and unsymmetrical in Y direction with 6 bays of 5 m length each in both directions and storey height as 3 m. Each building is analyzed for 6 different configurations categorized as Case I: Step back building, Case II: Step back & set back building, Case III: Step back building with X bracing, Case IV: Step back building with V bracing, Case V: Step back building with chevron bracing, Case VI: Step back building with diagonal bracing. All six cases for 6 storey building is shown in Fig 2. Geometrical properties of structural elements are same for all configurations as size beam = $230 \times 700 \text{ mm}$, size of column = $700 \times 700 \text{ mm}$ and size of steel bracing used = ISMC300. Slab thickness for all floors is considered as 150 mm and wall thickness as 230 mm for exterior walls and 115 mm for interior walls.

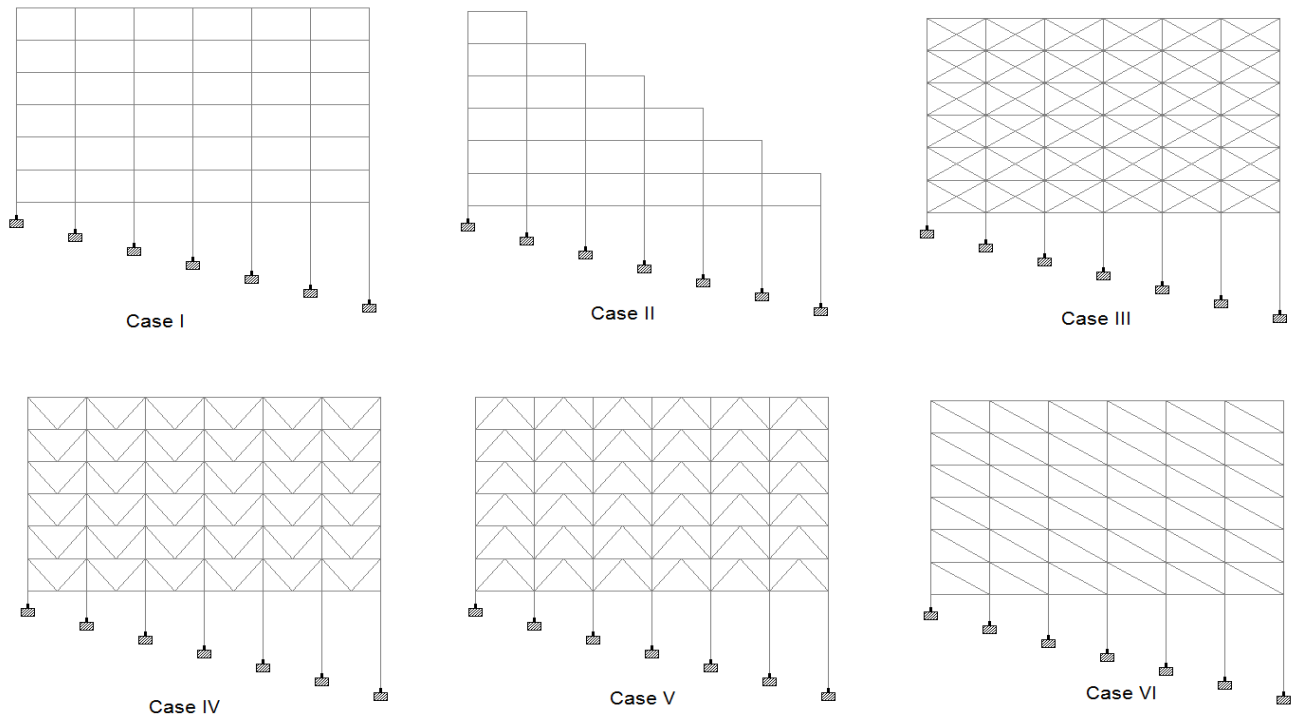


Fig. 2. Building Configuration for 6 Storey

2.2 Load cases and seismic parameters:

The dead load and live load are taken as per IS 875 (Part 1 and 2) : 1987, dead load and floor finish load is calculated as member load and floor load respectively corresponding to the material density and size of member and thickness of floor. For residential building live load is assumed as 4 kN/m^2 . To perform dynamic analysis seismic parameters

are considered as per IS 1893 (Part 1) : 2002. All configurations of step back buildings are assumed in zone IV with zone factor Z as 0.24. Building frame is assumed as Special Moment Resisting Frame, hence response reduction factor is 5 and Importance factor for important building is 1.5. Response spectrum analysis is performed for soil type as hard soil and damping ratio as 0.05 with spectral acceleration as 0.036.

3. RESULTS AND DISCUSSION

This study incorporate the performance of buildings resting on slope in hilly region having different storey building with same plan and same size of structural members and steel bracings to identify the deviation in performance. Step back buildings are provided with 4 different types of bracing having same location on exterior face of building. Performed analysis gives the results in terms of storey drift, base shear and fundamental time period presented in graphical form. Results represents as comparative analysis of each parameter in same storey building with 6 different configurations as Step back building, Step back and set back building, Step back building with X bracing, Step back building with V bracing, Step back building with Diagonal bracing, Step back building with Chevron bracing.

3.1 Storey Drift:

Performed analysis shows significant variation in storey drift of 6 different models of 3 different heights of buildings. Storey drifts for 10 Storey, 8 storey and 6 Storey with 6 different configuration are shown in Fig 3, 4 & 5.

10 storey building shows considerable change in storey drift for different configuration. It is 15.72 mm for step back building where as 8.36 mm in step back & set back building and 9.07 and 9.1 mm for step back building with Chevron bracing and with V bracing. 46.81% and 42.11% reduction in drift compare to step back 10 storey building and 37.30% and 35.87 % for step back building with X bracing and step back building with diagonal bracing.

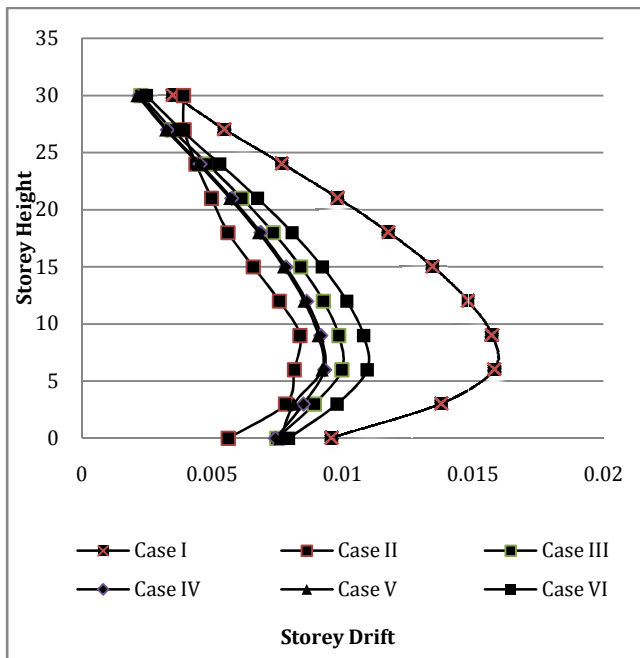


Fig. 3. Storey Drift for 10 Storey building.

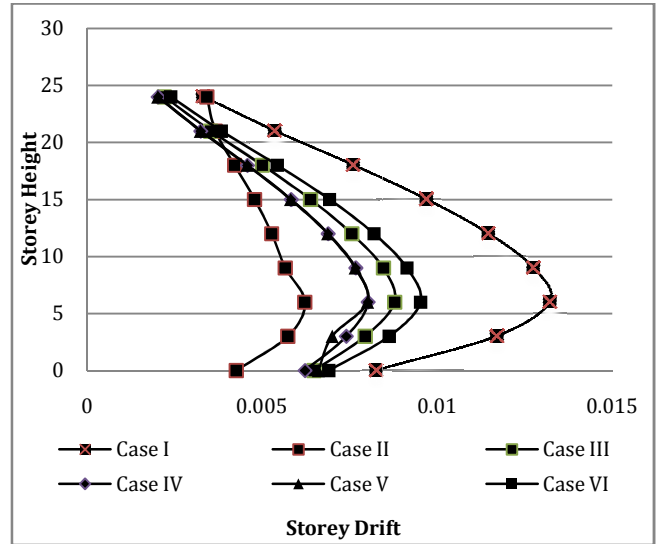


Fig. 4. Storey Drift for 8 Storey building

For 8 storey building, maximum storey drift is observed in step back building as 13.21 mm and minimum is observed in step back & set back building as 6.22 mm. 52.91% decrease in drift by provision of set backs in step back building, 39.36% in step back building with Chevron bracing and with V bracing, and 33.53% for step back building with X bracing compare to step back building

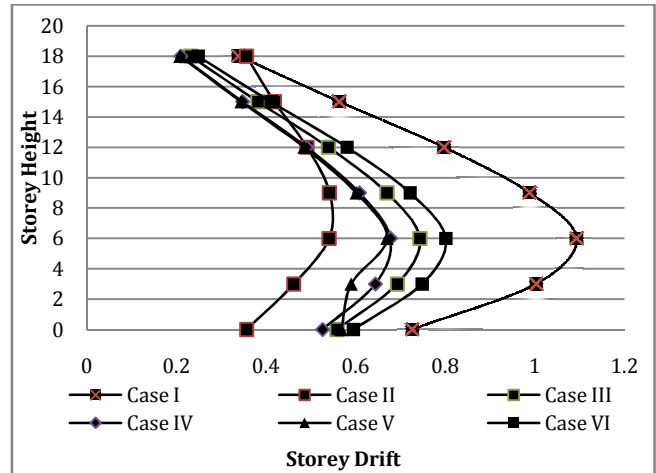


Fig. 5. Storey Drift for 6 Storey building

In case of 6 storey building, 10.93 mm and 5.40 mm drift is obtained in step back building and in step back & set back building shows considerable variation in displacement about 50.59% reduction in displacement and 38.7% for step back building with V and Chevron bracing, 32.29% for step back building with X bracing.

Results on storey drift shows significant reduction in drift by providing set back in step back building configuration. And among four bracing systems provided V bracing gives considerable reduction in storey drift.

3.2 Base Shear:

Base shear is maximum expected lateral force that will occur due to seismic ground motion at the base of structure.

It depends on soil type and weight of building at different floors. This study compares the base shear of all building configuration of step back building represented in Fig 6.

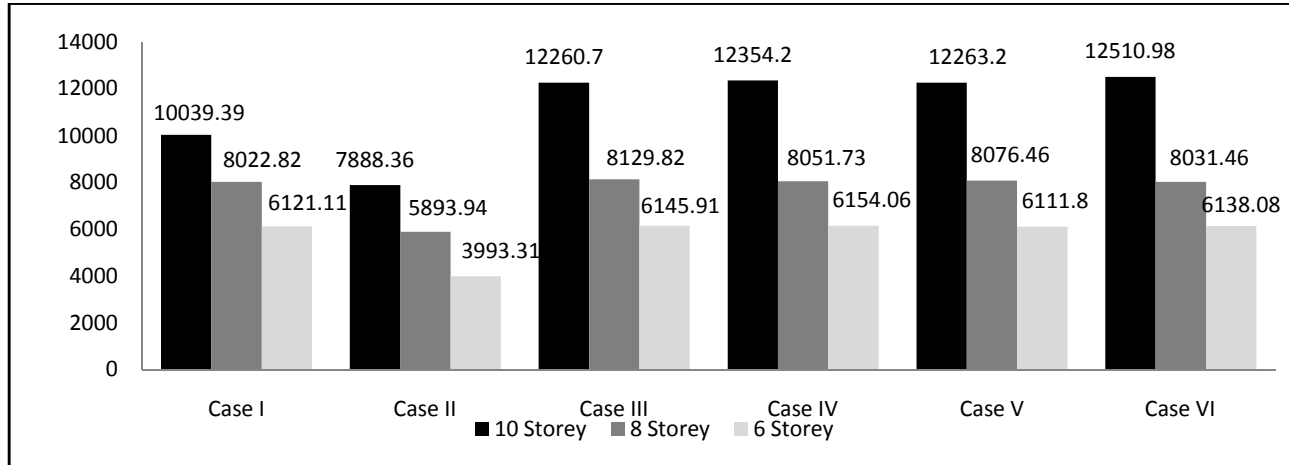


Fig. 6. Comparison of Base Shear

Results show variations in base shear according to building configuration and height of building. It shows maximum base shear for step back building in 10 storey, 8 storey and 6 storey building models and least in step back and set back building configuration. 21.43% base shear reduction is found in step back and set back building of 10 storey and 26.53% and 34.76% for 8 storey and 6 storey building of same configuration. 6 storey building shows maximum base shear in all configuration.

3.3 Fundamental Time period:

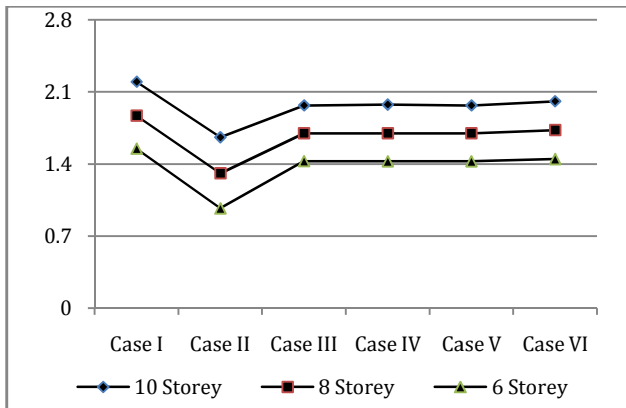


Fig 7: Comparison of Fundamental Time Period

The dynamic behavior of building is represented by fundamental time period. More flexible building and more mass of building shows more fundamental time period. Larger the flexibility more the displacement of building during the fundamental time period. Present study compares

the same parameter obtained during dynamic analysis on all building models and represented in Fig 7.

Results shows reduced fundamental time period in step back and set back building as 1.66 seconds about 24.51% reduction compare to step back building and 10.41% in step back building with X bracing, V bracing and chevron bracing in 10 storey. For 8 storey and 6 storey building gives 29.95% and 37.41% reduction in period of step back and set back building.

4. CONCLUSIONS

Building on hills with different configurations are been analyzed to know its behavior during earthquake in earthquake prone areas. For improving the performance, provision of bracing systems and set back in step back building has been made. Results discussed above conclude different aspects when buildings are to be constructed on slope with reference to the parameter as storey drift, base shear and fundamental time period. Following are the highlighted points of conclusions:

1. Storey drift can be minimized by providing Step back & set back building. Bracings in step back building also reduced storey drift compare to step back building.
2. Providing bracings increased base shear which attract more lateral forces towards building for which short column effect can be produced. Thus, for step back and set back building can reduce base shear and minimizes the possibility for failure.

3. Step back and set back building shows lowest fundamental time period among all models.
4. This study also shows the effect of height of building on its performance during earthquake. For lowest building height as 6 storey performs effectively in respective of all parameters studied.
5. To optimize the response of buildings on sloping ground, this study proposes to opt for small height building with set back in step back building to achieve minimum risk of failure. Furthermore in this system the columns are cut at different levels as the result the short column effect minimizes which further helps in optimization of cost of structure.

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Indian Scenario: Study of High Speed Rail Corridor, 2017

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Abstract: Indian high speed railway network 2020 vision, tracks and rolling stocks operates significantly faster than traditional rail traffic service system. Coverage proposed corridor projects details via available technologies, objectives, mechanisms and Present status has been discussed. Automated rail based system for traffic related to high-speed rail as business industries by Govt. of India involves Mini-Ratna public sector Rail Vikas Nigam limited (RVNL). Four working network consists, Delhi-Mumbai (Package-I), b) Mumbai-Chennai (Package-II), c) Delhi-Kolkata (Package-III) and d) DELHI-CHANDIGARH-AMRITSAR, to spread as future perspective in Special Purpose Vehicle. Benefits over conventional rail trend and special purpose rail running at 160-200 and 250 -300 kmph respectively emphasized w.r.t Indian Conditions in the present paper.

Keywords: Rail Corridors, 2020- HS-Rail, and Conventional rail, Bullet train

History:

In 1975 – 82

(Ref: https://en.wikipedia.org/wiki/InterCity_125),

InterCity 125 introduced by British Rail's named diesel-powered **High Speed Train (HST)** fleet. Other than Britishers, Countries like including Austria, Belgium,

China, France, Germany, Italy, Japan, Poland, Portugal, Russia, South Korea, Spain, Sweden, Taiwan, Turkey, UK, US and Uzbekistan also development of high-speed systems designed for passenger travel. Europe coverage to international borders also. China has 22, 000 kilometres (14, 000 miles) of Rail-HS as of end December 2016, accounting for two-thirds of the world's total.

TABLE 1: Available Technologies and Mechanism for Bullet Train & conventional time reduction

Name of High Speed Train	Train Between		Speed	Reduced Travel Time (Minutes /Hr)	Method	Mechanism	Source
Rejuvenation (Fuxing)	Beijing	Shanghai	350	5	China's Shanghai Maglev	Magnetic levitation	http://news.xinhuanet.com/english/2017-08/20/c_136541020.htm
Amtrak intercity high-speed trains	USA		241	-	Maglev Technology	Magnetic levitation	https://www.livescience.com/37195-japan-bullet-train-worlds-fastest-maglev-train.html
L0 Train (Japan)	Tokyo	Nagoya	500	-	Maglev Technology	Maglev train doesn't come into contact with the track while in motion, the ride is much smoother, acceleration and deceleration are faster	https://www.livescience.com/37195-japan-bullet-train-worlds-fastest-maglev-train.html
Under water Bullet Train	New york	Boston	354	94 minutes	Maglev Technology	Magnetic levitation	
Ultra high speed Hyperloop Tube track	Los Angeles	San Francisco	1220	30 minutes	Elon Musk	Low pressure tubes floating pods technology	https://www.livescience.com/50936-hyperloop-test-track-california.html
Under water Bullet Train	Mumbai	Ahmedabad	250	2 hours	Japan International Cooperation Agency	Tunnel based Maglev	https://www.thebetterindia.com/88051/india-first-underwater-bullet-train/

High Speed Rail Route Present status: In India, Ministry of Railways, Government of India, in terms of Public Private partnership. Railway system designed for speeds above 250kmph, called high-speed –sections implemented hierarchically by Japan, Spain, France and Germany. Among 16 World wide nations have high-speed railway, long spread of China 27, 000km of such tracks where tracks dedicated for high-speed trains stretch over 1, 000 kms. Unwillingness to newer production, government focuses on minor modifications to already present Rail-Infras'. But there is huge variation widely accepted is 200 Km/h i.e. 120 miles/ h. Some dedicated tracks and rolling stocks integrated high-speed rail system operates significantly faster than traditional rail traffic service system. Internationally, Japan first introduced in 1964 well known as Bullet Train.

Built, High-speed tracks of Continuously welded rail-on incorporates are grade-separated built, operated on standard gauge with large turning radius design pattern.

1. OBJECTIVES OF HS-RAIL IN INDIA

Documentary Coverage proposed corridor projects details via feasible studies and techno-economic investigations. Designing and planning; freeze technical parameters for HS-Rail at available assets, rolling stocks and operational conditions. Research part, main objective is financial modeling, public- private exploration, coordination with stakeholders and funding agencies, governmental clearances approvals. After clearancereal-estate development would be a key element of viability of these high-cost projects along with projects development, project executions, construction, up gradation, manufacturing, operations and maintenance of HS-Rail system or rail corridors. Automated rail based system for traffic related to high speed rail as business approved by Govt. of India.

Status/Role of HSRC

Subsidiary of RVNL on 25-07-2012 distinguished according to High Speed Rail Corporation of India Limited. Project proposed and launching, Delegates involved in H-S-Rail Corporation of India Limited by Shri Mallikarjun Kharge, (Hon'ble Minister of Railways on 29th October, 2013); Shri Arunendra Kumar, (Chairman Railway Board), Shri Satish Agnihotri (Chairman HSRC). 11/10/2017, International Conference ShriPiyushGoyal(Railway Minister, 2017) Addressed into about reliability, facilities atlong time coverage turned short time reach to destination. **Present status being, this** Special Purpose Vehicle has been incorporated in 2012 as a subsidiary of Rail Vikas Nigam Limited, which is a Mini-Ratna public sector enterprise of Government of India. Simultaneously, Managing Director MrAchalKhare (NHSRCL) declared project should be completed by Dec 2023.

Vision 2020

High Speed Rail Projects in terms of Article 69(2)(g) of Memorandum and Articles of Association of RVNL. Indian Railways' VISION 2020 envisaged High Speed Corridors. It was inspired by HS- rail corridor's revitalizing power of Railways in Japan, Europe, China, Taiwan and USA. India lonely planet not organized into HS- rail corridors.

Recent agenda being organizing into two prolong approaches. First raise the speed of segregated passenger corridors on trunk routes using conventional technology to 160 to 200 kmph. Second approach would be to identify a number of intercity routes, depending on viability, and build state-of-the-art high-speed corridors for speeds up to 350 kmph through on PPP mode in partnerships with the State Governments.8 corridors plan is proposed out of which under PPP partnership with state government at least 4 corridors of 2000 kms under construction at various stages of completion till 2020. Determined in 2015-16, Hon'ble Minister for Railways had announced of pursuance HS-Rail between Mumbai-Ahmadabad as first route of Bullet train for period of 2015-19 allocated Budget wasRs.65000 crore. Aspect will focus more on diamond quadrilateral, High Speed Rail & Elevated corridors commissioned.Japan Railway Technical Service (JARTS) was established in 1965 to provide advisories for High Speed railway, and its technical expertise has been inherited by JIC (Japan international Consultants). JIC deals with design, construction direction, O& M activities in a range of transportation system including urban rail and high speed rail and facilities for new transportation systems. Bullet train run between Ahmedabad-mumbai route claim total costs of 18.6 billion dollars[1]

Packages of work High-speed network

Contract Awarded For The Consultancy Of Feasibility Study For Diamond Quadrilateral Network Of High Speed Rail Corridors

a) Delhi-Mumbai (Package-I)

Feasibility Study Contract awarded to a Consortium of M/s The Third Railway Survey and Design Institute Group Corporation (CHINA) and Lahmeyer International (India) Pvt. Ltd, India

b) Mumbai-Chennai (Package-II)

Feasibility Study Contract awarded to a Consortium of M/s SYSTRA (FRANCE) - RITES- Ernest &Young LLP.

c) Delhi-Kolkata (Package-III)

Feasibility Study Contract awarded to a Consortium of M/s INECO (SPAIN) - M/s TYPASA- M/s Intercontinental Consultants and Technocrats Private Limited. Expected cost of 1583 km Delhi - Kolkata corridor is around Rs

84000 crores and is capable of reducing the travel time to just over 5 hrs from existing 17 hrs taken by Rajdhani.

d) DELHI-CHANDIGARH-AMRITSAR:

Pre-Feasibility study of this High Speed Rail Corridor is in progress. The consultant M/s Systra of France in Sep has submitted interim Report-II, 2015."HSRC-Delhi-Chandigarh-Amritsar High Speed Rail Corridor-India" contains information on the scope of the project including project overview and location. The profile also details project ownership and funding, gives a full project description, as well as information on contracts, tendering and key project contacts.

The "HSRC-Delhi-Chandigarh-Amritsar High Speed Rail Corridor-India" is part of Timetric's database of 82, 000+ construction projects. Database includes a 10+ year archive of completed projects, full coverage of all global projects with a value greater than \$25 million and key contact details for project managers, owners, consultants, contractors and bidders.

2. INITIAL PURPOSE OF PROJECTS AND FOREIGN INDUSTRY INVOLVEMENT

Tender work

Pending Tender work allotted to JIC, sept, 2017. According to report, Length of route is 534 Km [3]. It is likely to cover 11 stations at the speed of 320 Kmph (BKC, Thane, Virar, Dahanu, Vapi, Valsad, Surat, Bharuch, Vadodra, Anand and Finally Ahmedabad). It takes time of travel as 2 hours against 7 hours journey. Cost and budgets approximately Rs. 97, 636 Crores. It overcomes the Coverage given by Shatabdi express from Mumbai-Ahmedabad route. Involvement of industries corridor wise follows,

- Delhi-Chennai:

In Phase-I, Delhi-Nagpur section Under Government-to-Government cooperation, corridor upraised. Reports and logs for planning of HS- Rail corridor taken and completed by China Railway SIYUAN Survey and Design Group Co. Ltd. Feasibility study yet not done by group. High Speed Rail Corporation of India Ltd is the counterpart agency.

-Chennai-Bengaluru-Mysore:

China Railway ERYUAN ENGINEERING GROUP, feasibility studies in progress of speed rising for this section corridor. China Railway Eryuan Engineering Group has submitted Interim Report in June 2015. High Speed Rail Corporation of India Ltd is the counterpart agency.

-Mumbai-Ahmedabad:

Feasibility study was over past year. And RAIL VIKAS NIGAM LIMITED/ HIGH SPEED RAIL CORPORATION OF INDIA has been assigned implementation of high-speed rail projects. Mumbai-Ahmedabad is the first corridor,

which has been undertaken for implementation of proposed test project.

-FEASIBILITY STUDY OF MUMBAI - AHMEDABAD HIGH SPEED CORRIDOR:

MOU signed between JICA and Railway Ministry in 2013 and Joint feasibility report for Mumbai Ahmedabad HS- Rail system. JICA has submitted its Final Report of Feasibility Study of this corridor to Ministry of Railways in July 2015. Board members of Railway ministry decided to associate High Speed Rail Corporation of India Ltd. (HSRC) in this study.

Benefits and employment

Regarding Timetric project 'An individual travelling 100 km from Mumbai to Ahmedabad or vice-versa on work can commute in just about 30 minutes'. Due to HS-Rail, Mr. ArunJaitley (Finance Minister) says bullet trains potential in regenerating the economy but unless implemented. Direct benefits can be ensured by choosing effective economic model. Narendra Modi (PM, India) termed it into 'Suvidha' (facility), 'Suraksha', (Security) and will bring 'Rozgar' (Employment) and 'Raftar' (Speed). In near future it brings benefits into rural and urban sectors inequalities in various aspects like, employment, literacy, and infra facilities like health and sanitation viz bullet train. Various Townships and smart cities give hike to industrial development [2]. Industrialization report utilizes a wide range of primary and secondary sources, which are analyzed and presented in a consistent and easily accessible format. Timetric strictly follows a standardized research methodology to ensure high levels of data quality and these characteristics guarantee a unique report. This report provides details on the HSRC-Delhi-Chandigarh-Amritsar High Speed Rail Corridor-India including: Project description, overview and location, Ownership structure, funding status and key funding news for the project.

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- <https://www.thebetterindia.com/88051/india-first-underwater-bullet-train/>

Smart Grids Controlling Technical and Non- Technical Losses in Indian Energy Sector

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Abstract: Technical losses consist mainly of power supply dissipation because of faulty transmission and distribution lines, transformers and measurement systems. There are other losses incurred as a result of actions that are outside the control of the power supply system comprising electricity theft, non-payment by customers, and errors in accounting and recordkeeping. Power theft losses, also referred to as commercial losses, are difficult to estimate but run into huge amounts. India and Brazil rank high on the list. Countries such as the U.S. and the U.K. also experience these losses but they are not as significant. The Indian experience has also shown that electricity thieves come from across segments: domestic users, commercial and industrial establishments, rural areas and large cities. Most of the time, this theft happens through tapping of electricity from live wires, which also poses risks to people's lives. The use of smart meters thus becomes extremely relevant in developing countries such as India.

This paper highlights the latest developments in enhancing energy efficiency by utilizing smart grid technology towards cleaner environment and efficient energy generation and utilization

Keywords: Technological advancements, high-quality electric power service, better system reliability, high penetrations of distributed, renewable generation sources.

1. INTRODUCTION

Due to rapid technological developments, demand for quality and reliability, and the need for distributed renewable energy generation, developing countries have no choice other than integrating smart grid technologies in the upgrading and development of their power systems. The energy efficiency and the smart grid industries will see a rapid growth as the demand grows for reducing global greenhouse emissions, increasing amounts of renewable energy integration into the grid and rising prices of fossil fuels. With the successful and widespread development of smart grids, countries can expect high-quality electric power service, better system reliability, and quality of service. These maximize energy use and energy savings, and enable higher penetration and greater use of renewable energy sources to capture environmental benefits.

2. INDIA'S ELECTRICITY SECTOR FACES A NUMBER OF CHALLENGES

- Unremitting growth in demand for power, fuelled by the country's rapid economic growth and rising living standards
- Poor access to electricity in rural areas. Although the electricity grid reaches over 93% of urban inhabitants, just under a half of the rural population has no access to electricity

- Grid inefficiencies. Distribution line loss levels are the among highest in the world, averaging over 30%. The northwest of the country and rural areas are the worst affected.
- Theft of supply. Electricity theft is an issue in all areas of the country.
- Inefficient electricity usage, particularly in agriculture. Irrigation pumping is energy-intensive and accounts for a substantial proportion of all power consumption.
- Poor grid reliability. Outages are frequent, due to aging infrastructure, poor maintenance, and demand outstripping supply.

3. BENEFITS OF HAVING A SMART METER INSTALLED

An energy saving opportunity: Smart meters provide businesses with the chance to fully engage with, and take control of, their energy use. With improved insight into consumption patterns provided by online smart meter reporting, businesses can identify and pursue potential new saving opportunities.

The end of estimated energy bills: Smart meters will bring an end to estimated billing, this means that businesses will only pay for the energy they use. For business that uses energy in a consistent manner, the end of estimated billing

will enable them to forecast their energy spend. This increased functionality will also support time-of-use tariffs and allow businesses to access the benefits this can provide, leading to further cost savings on energy use.

Switching energy supplier will be easier than ever before: The introduction of smart metering has the potential to boost competition across the energy market. This will not only make it easier and faster to switch energy suppliers, but provide businesses with the best possible deals available. Currently it can be difficult for businesses to secure the data they need to switch energy supplier, making it difficult to compare and search the market for the best prices and the right contract.

Increased control of energy usage: Most businesses don't know how much energy they use with a third not understanding their energy bills. Smart meters are designed to give back control to businesses and consumers to rebalance the energy market. The greater visibility of energy usage will quickly help to identify patterns of usage, equipment that consumes a high amount of energy and view consumption levels across the business. When you combine usage data with real time consumption data businesses have

increased control over their energy usage and energy saving opportunities.

4. SMART GRIDS MITIGATING THE INEFFICIENCY IN POWER SYSTEMS

Smart grids help to mitigate the inefficiency in power systems by monitoring where energy is wasted, both from the viewpoint of technical and non-technical losses. Non-technical losses in developing countries can often be attributed to uncollected debt, tampered meters and inconsistencies in billing due to corrupt meter readers or illegal connections. Power theft often contributes significantly to overall system losses in developing countries, reducing the economic performance of utilities. They account for power losses between 15-25% in India, 15% in South Africa, 20% in Nicaragua; the main implications are financial losses for utilities, network instability and higher costs for honest customers. High-voltage distribution lines can help prevent illegal connections and improve power quality and reliability. A smart metering infrastructure can help reduce further theft. Additionally, meter-based tariffs incentivize an efficient use of electricity, which can result in considerable load reduction

5. DISTRIBUTED GENERATION POLICIES TO TAKE ADVANTAGE OF SMART GRIDS

Smart Capabilities	Smart Policies
Enable higher penetration levels of clean distributed generation	Provide incentives for clean distributed resources, adopt best practices for net metering, require advanced metering infrastructure to support net metering, 52 and enable excess power sales through RPS set-asides, state PURPA policies or feed-in tariffs
Accelerate deployment and allow interconnected distributed generators to operate during utility outages	Update interconnection standards and utility operations to reflect smart grid capabilities and provide incentives to distributed resources to provide new services for the utility system
Dynamically integrate distributed wind and solar resources	Improve utility planning for renewable resources and support mechanisms to reduce integration costs – for example, intra-hour scheduling
Optimize voltage and reactive power on distribution systems	Remove barriers to utility investments that improve distribution system efficiency – for example, through decoupling, where retail customer rates for recovering fixed utility costs are adjusted periodically to keep utility revenue at the allowed level
Increase demand response to allow loads to follow variable renewable energy resources	Offer customers dynamic pricing options and incentives for other types of demand response programs; provide customers with easy access to useful energy consumption data, evaluation tools and targeted advice foster innovation in the marketplace for controls that automate the customer's response; and incorporate demand response in integrated resource planning
Provide physical connection and communication with wholesale and retail markets	Provide access to new markets and revenue streams for customer owned distributed generation
Provide timely information on each distributed generator, including type and availability, allow	Better incorporate distributed generation into energy forecasting and RPS compliance

Smart Capabilities	Smart Policies
tracking for RPS compliance and reduce tracking costs	
Easier and timely interconnection distributed generation for exporting power to the grid	Provide transparent cost information and fair cost allocation for interconnection; streamline and update interconnection study requirements for exporting power to the grid

6. NOVEL SMART GRID PILOTS UNDER SMART GRID TASK FORCE IN INDIA

Cyan- the integrated system and software design company delivering mesh based flexible wireless solutions for utility metering and lighting control is presently providing Enzen Global Solutions Pvt. Ltd. (Enzen) for a large pilot project being implemented for Chamundeshwari Electricity Supply Corporation Limited (CESC), Mysore, Karnataka in southwest India. Enzen is awarded a contract to provide energy infrastructure solutions to CESC and Cyan will act as Enzen's end-to-end solution provider for the smart metering elements of the contract. Cyan will supply its 865MHz RF mesh communication network (including the modules, data concentrator units and head end software), a Meter Data Acquisition System and 21, 824 smart meters. Cyan will manage the supply chain through local meter manufacturer partners. In addition, Cyan will provide facility management services to CESC in Mysore for a period of two years post deployment, which is expected to represent around 10% of the order value.

The project is the first of 14 smart grid pilots under the Smart Grid Task Force in India being funded by India's Ministry of Power to be rolled out. This is the first commercial implementation of AMI technology by a public utility for consumers in India.

7. CONCLUSIONS

In India, though power theft is one of the strongest incentives to install smart meters, there are other compelling factors such as the need to reduce technical power losses and peak power deficit and bringing in more efficient transmission of electricity to rewarding consumers who help in reducing peak power demand. Currently, governments in Puducherry, Maharashtra, Andhra Pradesh, Karnataka and New Delhi have initiated the process of installing smart meters. Smart grid technologies will help utilities in India optimize efficient energy use in distribution networks, Smart grid technologies can enable utilities to employ demand response mechanism, curtailing power at the time of shortages and helping avoid blackouts. Additionally, integration of renewable energy like rooftop solar PVs into the grid will add to generation capacity.

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Role of Industrial Engineers in the Growth of Indian Foundry Industry

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Abstract: This study examines various role of Industrial Engineers in the Growth of Indian foundry industry. In this study, an importance of industrial engineering was identified pertaining to prosperity of Indian foundry. This study has attempted to identify need based areas with respect to their importance for effective use. The findings of this study may be used for developing curriculum activities in Industrial engineering field for benefit of Indian foundry.

Keywords: Indian foundry, Industrial engineering field, role Industrial Engineers.

1. INTRODUCTION

Indian Foundry Industry enjoying a status of the second largest producer of cast components in the world with about 10 million tons production per annum (Indian foundry congress, 2017).

India's foundry industry, which is the third biggest globally in terms of production capacity (10 million tonnes in FY16) after China (40 million tonnes) and the US (11 million tonnes), has an installed capacity of 15 million tonnes per year.

Foundry Industry has a turnover of approx. USD 19 billion with exports approx. USD 2.5 billion. However, Grey iron castings have the major share i.e. approx 68% of total castings produced. The Indian foundry industry manufacturers metal cast components for applications in Auto, Tractor, Railways, Machine tools, Sanitary, Pipe Fittings, Defence, Aerospace, Earth Moving, Textile, Cement, Electrical, Power machinery, Pumps / Valves, Wind turbine generators etc.

Steel 380 magazine(May 2017) India (<http://news.steel-360.com/steel/growing-demand-foundry-sector/>)

Market research analysts have predicted that the foundry market in India will grow steadily in coming year over 10% by 2020. This market research analysis identifies the role of Industrial Engineers in the Growth of Indian Foundry Industry (Technavio reports, 2017)

In this paper, various roles of Industrial Engineers have been chosen on the basis of literature review. This paper is organized as the main sections namely areas, Discussions, Conclusions and future scope.

2. AREAS WHERE INDUSTRIAL ENGINEERING APPROACHES CAN BE USED

2.1 Marketing

In early days marketing work might be suitable for non technical paper but now a day's techno-commercial knowledge is very much essential in highly competitive work. In foundry this techno-economic knowledge reduce the burden during process improvement . Marketing Research means developing research questions, collecting data, analyzing it and drawing inferences, with a view to making better business decisions. Marketing must target and communicate with engineers and technical buyers. (Pahl, G., & Beitz, W., 2013; Scheer, A. W., 2012). Indian foundry has huge demand in automobile industry within India also(Foundry Informatics centre, 2017)

2.2 Casting Development

APQP (Advanced Product Quality Planning) is a scientific method of defining and establishing the steps necessary to ensure that a product satisfies the customer. Effective product quality planning depends on a company's top management's commitment to the effort required in meeting customer specifications.

Design failure mode and effects analysis

Design for manufacturing and assembly

APQP is an emerging field among researchers. Some studies have reported the successful use of the APQP for quality improvement in existing products. APQP have evolved to with product development and process improvement. The growth of APQP focus on quality methods. It provide a inclusive and flexible system for maximizing business profit and has been considered

revolutionary system (Kalpakjian, S., & Schmid, S. R., 2014; Mittal, K., Kaushik, P., & Khanduja, D., 2012).

The series of resins obtained, now a days. These resins (binders) and acids (catalysts) make a two part no bake self-set system (popularly known as FNB in foundry terms) With growth of Foundry industry, several self-sets have been introduced periodically for making molds and cores. Other primitive binders like cement, molasses and many proprietary binders have largely been replaced by modern organic binders, which meet requirements of higher productivity, better out of box and handling strength of molds and cores, rapid production cycle, better de-coring property and eventually better casting finish. Furan sand is very useful in all above conditions (Ghosh, D., 2013).

Foundries which use CAD/CAM as well as simulation tools reported 30% faster casting development also 50% lower rejection rate, compared to foundries which do not employ these technologies. Few years back, the main concern for both CAD/CAM and simulation technology was cost, whereas today the concerns have changed to technical support as well as trained manpower availability. The survey focus many such insights useful for technology strategy planning at all foundry level (Joshi, D., & Ravi, B., 2010).

Manufacturing simulation is a digital engineering tool and procedures have had a positive impact on the manufacturing industry. The increased competition in the global marketplace is forcing industrial manufacturers to develop their production systems by increasing flexibility, improving quality and lowering production costs. With the aid of simulation techniques, the understanding of manufacturing systems may be enhanced and alternative solutions may be tested. Simulation has, thus, played an active role in industrial development in early years (Petter Solding, Damir Petku & Nawzad Mardan, 2009; V.S. Saravanan (2017)

2.3 Environmental Engineering

Regarding industrial pollution, environmental acts have been getting very stringent in various countries and efficient use of resources is having great importance. Industries are always under pressure to improve environmental performance of manufacturing activities based on waste management principle, From 2004, the pollution prevention activities in the western countries resulted in a reduction of 25% in waste generation while 34% increase in industrial production (Grasso, D., & Burkins, M. 2010; Fore, S., and C. T. Mbohwa, 2010).

From 1980s onwards, most of foundry industries, marked as environmentally destructive, In the view of Cleaner production, thus productive goals levelled with environmental issues now become essential, which focus the necessity for the development of environmental

performance indicators that are able to expose impacts of industrial operation on the environment the definition of indicators for environmental performance analysis (EPA) must consider the specifications of produced goods and the nature of adopted processes. (Rebelato, M. G., et al, 2017). Over the last 10 years, stringent regulations put the manufacturing industry to take serious actions towards greener production through implementation of best available techniques (BATs), industrial waste still need guidance to minimize environmental impacts of manufacturing processes. The foundry industry remains one of the most i waste generating fieldr and therefore, iron casting and used a life- cycle approach (LCA) to evaluate the performance and cross-media effects of the BATs applicable for this industry(Yilmaz, O., Anctil, A., & Karanfil, T., 2015).)

With very limited resources and their disposal, foundry small and medium-sized firms always find themselves unable to cope up with the changes necessary to meet environmental regulations and product controls. Small-scale operations such as metalworking, casting, machine tools etc. are frequently among the worst offenders of environmental regulations across world. Energy saving systems may be well suited to the requirements of SMEs for pollution control or waste disposal.(Wadhwa R.S. 2014)

Sustainable manufacturing seems to be a rapidly developing areas and it would be expected that there is a growing body of knowledge in this field (Despeisse, M., Mbaye, F., Ball, P. D., & Levers, A. 2012).

Environmental factors may play a major role in selecting an optimal process planning scheme. (Shojaeipour, S., 2015)..

2.4 Energy Management

Foundry is an energy intensive industry. Energy costs for foundries are about 15% of the cost of castings. In early years foundries have become energy aware and most of medium scale have installed on-line energy monitoring systems for report energy consumption (kWh) per tonne(Schulze, M., Nehler, H., Ottosson, M., & Thollander, P., 2016).

Energy efficiency is recognized as a primary measures to increase the competitiveness of the indus- trial sector, and in particular for small and medium-sized enterprises (SMEs), in which energy efficiency measures. Hence, it is very crucial to have a precise as well as punctual knowledge of the barriers to be handled in the decision-making process of adopting an energy management process (Cagno, E., Ramirez-Portilla, A., et al, 2015; Noro, M., & Lazzarin, R. M., 2016; May, G., Stahl, B., et al, 2016)

Although the energy saving in a foundry is a very difficult task, realizing heat recovery, may give rise to an energy saving up to 20%. Regarding the production process in cast

iron. Further savings may be possible after careful analysis ((Sa, A., Thollander, P., & Cagno, E., 2015; Lazzarin, R. M., & Noro, M., 2015; Arjunwadkar, S. et al).

2.5 Safety Engineering

A workers working in very hot environment is at more risk of heat-related disorders and safety problems. Thus safety needs to evaluate the risk and warning rate of hot environment without compromising productivity of the organization.

Improvement of quality of casting and manufacturing processes is a difficult task, but it is beneficial for the foundry. In order to manufacture casts properly in terms of quality, at the lowest own costs possible, it is essential to improve the manufacturing systems at all stages of manufacturing processes, through elimination of waste, as well as inconvenient and dangerous activities. Good organization is employee-friendly and it promotes occupational health and safety. Various safety measures are to be implemented in coming year (.Ilangkumaran, M et al., 2015; Kukla, S., 2016; Sen, S., 2014)

The reliability analysis of the casting process is useful in foundry work using a probabilistic approach. Foundry in many developing countries suffering from poor quality due to improper management, lack of resources and very wrong working practices, which results in the decrement of productivity(Kumar, A., Varshney, A., & Ram, M. 2015).

2.6 Maintenance Engineering

The foundry industry focus has changed from a labour-intensive to a technology-intensive industry. However, technology cannot be effective without excellent maintenance management (Saniuk, A et al, 2015; Kumar, A., Varshney, A., & Ram, M., 2015)..

2.7 Quality Management and system Engineer

Lean manufacturing is often seen as a set of tools that reduce the total cost and improve the quality of manufactured products. The lean management philosophy is one which targets waste reduction in every facet of the manufacturing business; however, only recently have studies linked lean management philosophies with improving environmental sustainability. The foundry industry, has significant challenges in the current regulatory and political climate with developing an economically and environmentally sustainable business model. Lean manufacturing always proven as a model for both economic sustainability as well as environmental stewardship. Several recent studies have shown that both lean and green techniques and “zero-waste” policies also lead to reductions in overall cost. While these strategies have been examined for general manufacturing, they have not been investigated in detail for the foundry industry.

Presently lean and green manufacturing are the two most important strategies for improving operations and achieving service excellence in manufacturing industries. Lean manufacturing is being extensively practiced and implemented by different industries in many countries throughout the world for improving productivity (Desai DA, 2012.. Singh, T., & Dubey, R., 2013 Suresh Prasad Dinesh Khanduja, 2016)

2.8 Value Engineering

Product life cycle is challenge facing manufacturers presently as efforts to increase efficiency throughout the life cycle do not only lead to an extended responsibility of the concerned parties. As a result, economically successful business areas can be explored. Whether new service concepts are required, new regulations have been passed or consumers values are changing, the differences between business areas are disappearing. “Life Cycle Management” (LCM) considers the product life cycle as a whole and optimizes the interaction of product design, manufacturing and life cycle activities. The goal of this approach is to protect resources and maximize the effectiveness during usage by means of Life Cycle Assessment, Product Data Management, Technical Support and last but not least by Life Cycle Costing. This paper shows the existing approaches of LCM and discusses their visions and further development (Salonitis, K et al., 2016)

Foundry technologies realized with aid of the processes allocation provides an opportunity to arrange a holistic picture of its resource efficiency and the expenses at the various stages of its life cycle. The review of the processes and activities for the whole chain of creating an added value allows defining the most expensive stages and, therefore, creating the opportunities for applying the resource-saving technologies (Vidayev et al., 2014; Nallusamy, S, 2016). Expert systems in technology can be used now a days to increase the productivity in a comprehensive ways (Macioł, A., Wrona, R., & Stawowy, A, 2016; Zimwara, D., 2013)..)

2.9 Activity Based Cost saving

Product life cycle is challenge facing manufacturers presently as efforts to increase efficiency throughout the life. “Life Cycle Management” (LCM) may be the product life cycle as a whole and optimizes the interaction of product design, manufacturing and life cycle activities. The goal of this approach is to protect resources and maximize the effectiveness during usage by means of Life Cycle Assessment, Product Data Management, Technical Support and last but not least by Life Cycle Costing.

Activity-Based Costing (ABC) is a cost accounting method that can overcome many of the limitations of Traditional Cost Accounting (TCA) methods. Cost for each department in the foundry are estimated by regular engineering procedures. But cost- estimating relationship model that

mathematically describes the cost of final castings as a function of all consumable resources is constructed. A Work-In-Process (WIP) flow through the different production centres is analyzed and costs of available resources are allocated for all foundry centres, cost rates are derived, accordingly the ABC method for estimating production cost is discussed and presented. Comparison between the results of ABC method and the results of TCA method has been carried out. Finally results are discussed, recommendations are presented, and avenues for related future works are proposed (Al-Tahat, M. D., & Abbas, A. R. 2012).

3. DISCUSSIONS, CONCLUSIONS AND FUTURE SCOPE

This study has attempted to identify the most important role. Based on the literature review. We may focus on right balance between technological up gradation and internal operational excellence through various tools and techniques like Total Productive Maintenance (TPM), Value Stream mapping (VSM), Maynard Operation Sequence Technique (MOST) any many more to improve our efficiency and efficacy as well in terms of Production, Quality, Cost, Delivery, Safety, Morale and Environment. Specific initiatives like lean approach with frugal mind set in utilizing all our resources at optimal level and focus towards elimination of waste in our process drives us towards becoming cost competitive

These roles may help managers of industry to resolve the critical issues. Industrial engineers possess a bachelor's degree, but very few typically in industrial engineering. However, many industrial engineers have post graduate degrees after mechanical engineering, electrical engineering, manufacturing engineering, industrial engineering technology, or general engineering. Above discussed points are suitable for industrial engineering field.

In the future research to determine weights of the each field a sub branch of Industrial engineering may be possible as per need.

In this study there were only 9 fields are taken in consideration, but more fields can be included and resolve in future.

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A Study of Factors Affecting Entrepreneurship in Industries at Madhya Pradesh

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Abstract: Individuals innovate and to create new businesses. Many support mechanisms act as a facilitators and promoter of entrepreneurship. Risk taking, innovation, creativity and learning from past are some of the few important characteristics of an individual who aspires to become a successful entrepreneur. to result into change within the organization. Entrepreneurship is a level field and all have equal opportunities to perform, it is one who exploits himself completely for the cause becomes successful. In This study, various factors affecting entrepreneurship in the state of Madhya Pradesh was researched. The sample of 80 entrepreneurs and would be entrepreneurs was drawn on random basis in the state of Madhya Pradesh.

Keyword: entrepreneurship, Madhya Pradesh

1. INTRODUCTION

The significance of entrepreneurship and innovation as a mechanism for growth has been a widely accepted concept (Peters and Waterman, 1982; Kanter, 1983; Drucker, 1985; Pinchot, 1985; Slevin and Covin, 1990). Covin and Slevin (1991) suggested that entrepreneurship is studied for many reasons but the over-riding reason for the current interest is the widespread belief that entrepreneurial activity stimulates general economic development as well as economic performance of individual firms. From macro social (promotion of economic growth in the developed and developing countries) and organisational level (improvement of organisational performance) considerations, a further study of various modes of management may have high social relevance. Schollhammer (1982) stated that entrepreneurship is the key element for gaining competitive advantage and consequently greater financial rewards. In a competitive environment, entrepreneurship is an essential element in the long range success of every business organisation, small or large, new or long-established. Firms adopt entrepreneurship in the hope and under the assumption that the associated behaviours will help to create or sustain a high level of performance (Cornwall and Perlman, 1990).

2. ENTREPRENEURSHIP PHENOMENON

Trends identified in business state that dynamic corporations of the future should simultaneously be trying alternative ways of doing things in competition within themselves. Many organizations today do not pay employees for attendance, but pay the competing groups for modules of work done. These groups may be in the form of pools contracted for a certain amount of work over a certain time period for a lump sum. The members of the pool would be responsible for apportioning work, fixing pay,

setting work hours or even whether to subcontract part of the work.

Entrepreneur seems to be one of the most important elements for entrepreneurial success. The importance of entrepreneurial role has been emphasized by many researchers. Gobeli and Rudelius (1985), Pinchot (1985), and Sexton and Bowman (1985) discovered that the various roles performed by an entrepreneur vary in importance according to the stage of the innovation process.

He is an inventor, decision-maker, sponsor and programme manager. This suggests that different individuals with different characteristics may be required by a company at different times, and for different types of work. The type of organisation, its life-cycle stage, its size, and its rate of growth all therefore have a bearing on the source and types of individuals it will appoint to its key roles. Kirton (1984) proposed Kirton Adaption-Innovation Inventory. Adaptors produce a sufficiency of ideas, but these are based on an existing definition of a problem, in other words doing something "better". Adaptors accept the paradigms and familiar assumptions underlying an organisation, hence their solution is more palatable to the establishment which shares those assumptions. Innovators, in contrast, do things differently.

Their proposals are less expected, and thus less acceptable. Innovators are likely to be treated with suspicion. They are seen as abrasive and insensitive, who appear unaware of the havoc they cause. Kirton suggests that organisations in general, and especially large ones, tend to be adaptive in order to minimise risk. Over time, organisations develop, through recruitment, a cognitive style mean. In order to implement changes, individuals have to be different from the organisation's current mean - thus adaptors will act as

change agents in innovative environments, and innovators in stable environments.

The team may be comprised of many employees within the corporation. Within the corporate setting, there are more people and roles involved in the entrepreneurial process (Gobeli and Rudelius, 1985) than in the conventional linking of entrepreneurship with the founding and development of a firm, sponsors i.e., senior managers who support the progress of the innovation, godfathers i.e., top-level managers who give their blessings to the process, and inventors i.e., the originators of the idea, as well as the champions who develop and push for the implementation of an innovation, all have a legitimate claim to the title of corporate entrepreneur. The entrepreneur should possess personality traits so as to harness potential of all concerned in the project. Howell and Higgins (1990) described an entrepreneur as a champion. Entrepreneur must be a good opportunity identifier.

3. ENTREPRENEURSHIP IN MADHYA PRADESH

State of Madhya Pradesh is rich in natural resources and also has been hub of activities as it the central part of the country. Due to its strategic location, resources it has tremendous potential of entrepreneurship. As compared to states like Gujarat Maharashtra, Punjab state of Madhya Pradesh is low in entrepreneurship but this also provides an opportunity for would be entrepreneurs. There are traditional industries which are conventional, low technology and labour/semi-automated which are evolutionary in nature with very slow phenomenon of development and change. Many of these are process industries where the sub-processes are interrelated and not independent. Also there are hi-tech industries. These industries are mechanized/ automated/knowledge-based and use latest upgraded technology. In these types of industries, adoption of advanced technology is very fast. They have extended knowledge base and are revolutionary in nature.

4. OBJECTIVE OF THE STUDY

To determine the factors affecting Entrepreneurship in Industries at Madhya Pradesh.

5. RESEARCH METHODOLOGY

The present investigation is an exploratory study to determine the factors affecting Entrepreneurship in Industries at Madhya Pradesh.

6. THE DESIGN & SAMPLE

The sample of 80 entrepreneurs and would be entrepreneurs was drawn on random basis in the state of Madhya Pradesh while controlling the effect of extraneous variables such as gender, background, education, and hierarchy by randomization and elimination. The incomplete sets of

measures were rejected besides those in which socially desirability scores were found beyond optimum range.

7. TOOLS FOR DATA COLLECTION

Primary data was collected as per requirement of the research design. For this, one standardized psychometric measures were developed to elicit the responses from entrepreneurs and would be entrepreneurs.

8. RESULTS

Factor analysis resulted into following factors which affect entrepreneurship in the state of Madhya Pradesh..

1. Technology transfer
2. New product development
3. Ancillary promotion
4. Marketing Channels
5. Quality support system
6. Training and Development
7. Entrepreneurship promotion policies
8. Infrastructure availability
9. Financial schemes
10. Trained Labour
11. Power
12. Export promotion
13. Alternate resources.

9. CONCLUSION

Factors affecting entrepreneurship in the state of Madhya Pradesh are Technology transfer, New product development, Ancillary promotion, Marketing Channels, Quality support system, Training and Development, Entrepreneurship promotion policies, Infrastructure availability, Financial schemes, Trained Labour, Power, Export promotion, Alternate power resources. For flourishing entrepreneurship in the state of Madhya Pradesh formal measures need to be taken to promote these factors. Policy makers can use these factors to make conducive policies, agencies engaged in the promotion of entrepreneurship may priorities their preferences as per these factors. Training and development institutions in the field of entrepreneurship should increase their efforts and agencies in the field of quality control should make easy access for entrepreneurs.

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Optimization of Man Power in Warehouse by Using Lepaksnel Model

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Abstract: It has become increasingly difficult for business to keep a competitive edge in the global market. The increase in price of the products directly affects the profits of the business. It has become imperative for the organizations to cut the operating cost while remaining more efficient and effective in terms of product and its quality. In the wake of becoming more cost efficient, more and more firms are opting for outsourcing of functions which are not considered as their area of expertise. Strategic outsourcing is considered as an important tool for implementing rapid strategic changes.

The case study tries to reengineer the process of material issuance from warehouse and the use of strategic outsourcing in warehouse. The business has initiated a project to reduce the floating inventory of stores at individual department by planning to run the store two shifts per day and start door to door delivery of materials from the store to respective departments.

Keywords: Strategic outsourcing, Warehouse, BPR, Rationalization

1. INTRODUCTION

The mining area is currently going through the expansion phase, so it has been imperative for them to work more efficiently and effectively. Looking at the material requirement of the department and to reduce the floating inventory it was decided to operate stores department in 2 shifts (General & 2nd Shift). With the increase in shift operation the need for the increase in manpower will be dealt by strategically outsourcing of activities with low strategic value.

2. ANALYSIS OF EXISTING SYSTEM

In the existing system of store there are mainly three sections for Material receiving & verification.

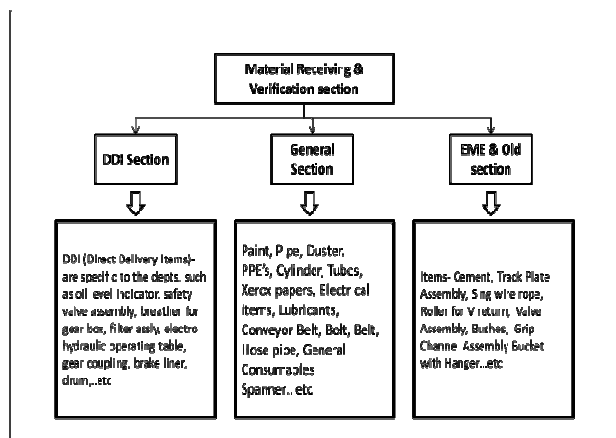


Fig. 1. Major sections in Central Stores

2.1 Material & Process flow Mapping

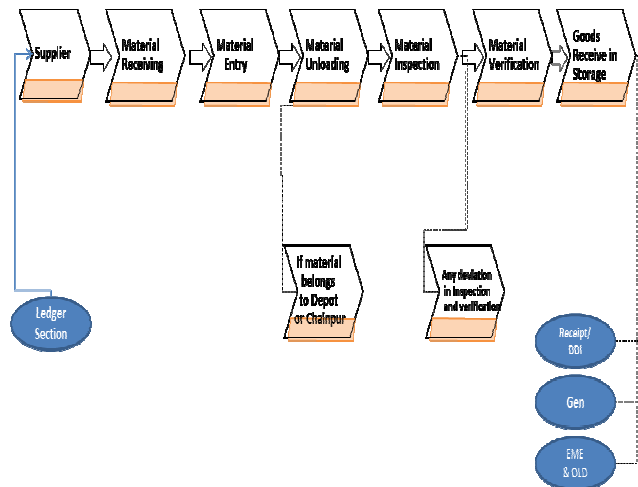


Fig. 2. Existing material flow

The existing material flow starts from indenting of material to receiving of material at each of the sections dedicated for the type of material. For the current functioning of stores the manpower deployment in various sections of store is shown in table below. The persons deployed are for receiving, storage & issuing of goods. Each department sends its own resources to bring material from central stores.

The process of issuing of material is shown in flow diagram mentioned below. The process starts from indenting of material by raising material requisition and ends at material receipt at the department.

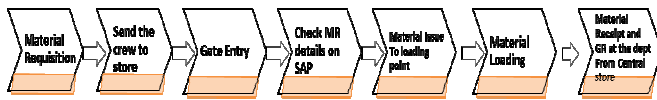


Fig. 3. Current Material issue process

3. NEW REQUIREMENT FOR STORES

Division has taken inventory management project to reduce the floating inventory in individual department at Division and planning to run stores in 2 shift operations (General + B shift) for Material Issue from central store to individual departments. B shift operation will run only for spares delivery of Beneficiation plant. Cement, Steels and all other heavy material will be issued in General shift. Out of total inventory 70-75% of inventory is belong to beneficiation group. Door to door delivery of goods to individual departments.

As a part of evaluating requirement the process of material issuance was reevaluated and redesigned.

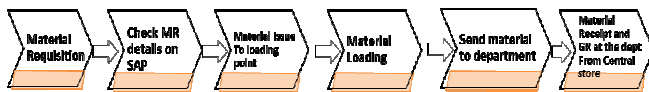


Fig. 4. Proposed Material issue process

With the new process there will be elimination of two steps “send the crew to store” & “gate entry” and addition of a step of “send material to department”

4. STRATEGIC OUTSOURCING & MANPOWER PLANNING

Many employers carefully select a core group of employees, invest in them, and take elaborate measures to reduce their turnover and maintain their attachment to the firm. For this they outsource certain type of jobs to service providers. This is done by using Lepak & Snell model shown below.

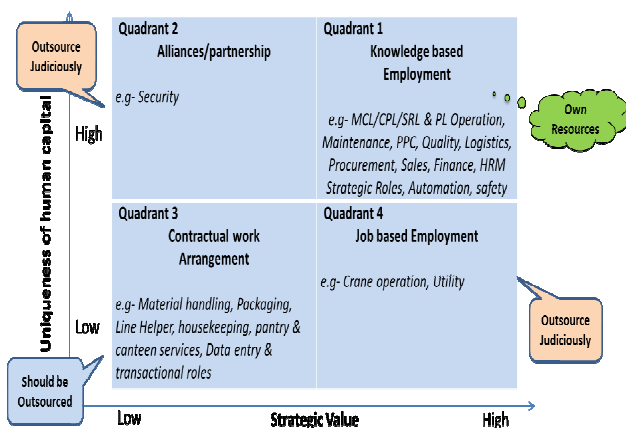


Fig. 5. Operating Philosophy (Lepak & Snell's Model)

On the basis of this model the jobs with high strategic value and high uniqueness of human capital should be retained and one with low strategic value and low uniqueness of human capital can be outsourced. Other than the two mentioned category can be outsourced based on discussion and their role and requirement to the company.

For the current deployment of Manpower for b shift operation it will require provision of additional store keeper and mazdoor for running store in B Shift. A total of four people will be required. For door delivery system presently each department sends its own resources for bringing material from central stores. With the proposed system a central door delivery team will supply material from Central stores to individual departments. Door delivery operation will run only in General-shift and it will be managed by service providers, however to coordinate the activities of door delivery team one person on company roll will be required.

Shifting of material within the premises of central store is of low strategic value and low human capital it can be managed by deploying resources through service providers resulting into rationalization of one person on company role. Implementation of Door Delivery system will lead to rationalization total of six mazdoor and drivers engaged by individual departments for bringing material from central store. Rationalization three Supply Associates PR and other related activities will be done by Officers provided with the departments. Merger of sub-stores of beneficiation plant & engineering services to have a common department store each. This will result rationalization of three stores assistant.

Final deployment of persons after 2 shift working & door delivery of goods to the department is shown in table below.

5. CONCLUSION

Designation	Existing	Proposed	Change Wrt Existing	Remarks
Level 1	3	5	2	
Level 2	7	7	0	
Level 3	7	8	1	
Level 4	1	1	0	
Level 5	8	8	0	Note- Home delivery will be managed by service providers
Level 6	12	0	-12	They are deployed for help in material unloading/handling, tying sling on cranes during

Designation	Existing	Proposed	Change Wrt Existing	Remarks
				material receiving at the central stores. Material receiving and Verification(Receipt section)
Level 7	1	0	-1	Driver to be managed by service provider
Total Stores	39	29	-10	

With the help of lepaksnel model there will be rationalization of 13 people as those jobs are low end jobs which have low skill level requirement and low criticality.

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Measuring Emotional Labour of the Employees in the Hotel Industry

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Abstract: The study was undertaken with the objective to identify the dimensions that will help to measure emotional labor of the employees in the hotel industry. Descriptive research design was adopted for the study. The sample unit was hotel employees. Non probability convenience sampling procedure was adopted and 280 hotel employees were personally contacted to measure the emotional labor experienced by the employees. Data were collected through structured questionnaire. Factor analysis was conducted for data reduction and dimension identification. Employees do more of surface acting when interacting with hotel guests. Situations should be created where employees should exhibit less of surface acting. Management need to internalize the hotel process so that employees exhibit deep acting when delivering services to the customers. Employees in the hotel industry experience emotional labor because of customer orientation. Self awareness is an important variable which affects emotional labor.

Keywords: Emotional Intelligence, Emotional Labor Acting Strategies, Customer Orientation, Recognition (Self Awareness), Surface Acting, Emotional Dissonance, Job Strain, Hotel Industry

1. INTRODUCTION

Due to increased competitions in the hospitality industry, organizations place much emphasis on “service with a smile” to maximize service quality and customer satisfaction. Managing service employees’ emotional display has been recognized as an important aspect of maintaining loyal customers. Frontline employees directly interact with customers and are also referred as boundary spanners. They are the connecting link between the external customer, an environment and the internal operations of the organization. They serve a critical function in understanding, filtering and interpreting information to and from the organization and its external constituencies. Their skills and experience covers the wide range of jobs and careers. In industries such as the fast food, hotels, telecommunications and retailing, the boundary spanners are the least skilled, lowest paid employees. They are the order takers, front desk employees, telephone operators, store clerks, truck drivers and the delivery people. But in the other industries, they are well paid, highly educated professionals- such as doctors, lawyers, accountants, consultants, architects and the teachers. Boundary spanning positions are often high stress jobs. A part from the mental and physical skills, these positions require extraordinary levels of emotional labor, they often demand an ability to handle interpersonal and organizational conflict and call on employee to make real time trade-offs between quality and productivity on the job. These stresses and trade-offs results in service delivery failure creates a bad impression on the customers. Service organization demands from their employees to show some positive emotions to their

customers and to hide their negative emotions such as anger and frustration. This concept of following the expressional norms of organization by the employees is termed as emotional labor. “It is what employees perform when they are required to feel or at least project the appearance of certain emotions as they engage in job relevant interactions (Hochschild, 1983)”. The objective of the study is to identify the dimensions related to emotional labor experienced by the employees in the hotel industry.

2. LITERATURE REVIEW

The hidden role of emotions in performing the duties effectively at workplace was first put forth by American sociologist, Arlie Hochschild, in 1983 in her book, “The Managed Heart: The Commercialization of Human Feelings”. Her work drew inspiration from the dramaturgical perspective put forth by Erving Goffman. The dramaturgical perspective urged that the work place is the stage where employee is the actor and the customer is the audience. The labor which was performed in terms of emotion was thus called an emotional labor. According to Hochschild, emotional labor is the labor that which goes beyond the physical and mental skills needed to deliver quality service. It means delivering smiles, making eye contact, showing sincere interest and engaging in friendly conversation with the people who are essentially strangers and who may or may not be ever seen again. Friendliness, courtesy, empathy directed toward customers require great amount of emotional labor from the frontline employees. It often requires employees to suppress their true feelings to be effective in their jobs. A frontline employee who is

having a bad day or isn't feeling just right is still expected to put on the face of the organization when dealing with the customers'. She defined emotional labor as "The management of feeling to create facial and bodily display with a focus on showing appropriate organizationally desired emotions". For emotional labor to take place at the work place, three conditions should be fulfilled to:-First, they require employees to interact face-to-face or voice to-voice with other people, like clients, customers, and guests. Second, they require the worker to produce an emotional state in another person. Third, employee's emotional expressions are formed by organizational prescribed display rules and requirements.

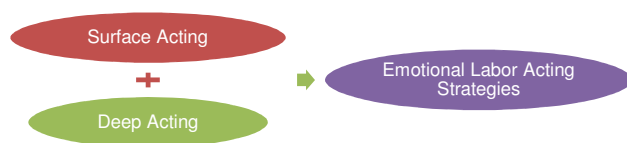
Through Factor analysis 6 dimensions were identified to measure emotional labor of the employees which are presented below:-

2.1 Emotional Intelligence

It is the individual's capability to identify and understand emotional information and to generate and regulate emotions that promote emotional and intellectual growth (Salovey and Mayer, 1990). It is a set of individual's capabilities to understand, regulate, use, and manage their emotions (Law et al., 2004). Conceptualization and operationalization of Emotional intelligence can be viewed from the ability model and the mixed model (Van Rooy and Viswesvaran, 2004). It is characterized by considerable face-to-face and voice to voice interaction of frontline employees with customers, so the frontline employees are required to manage, regulate, and control their emotions effectively (Karatepe, 2011).

2.2 Emotional Labor Acting Strategies

Emotional Labor employees usually use two distinctive acting strategies to satisfy organizational requirements for emotional expression (Hochschild, 1983):-



Surface acting (Faking the expected emotions) -It refers to the management of external emotional expression without any changes in inner feelings. Grandey (2003) states that surface Acting corresponds to response-focused emotional

regulation in which employees modify the outward expression of their emotions through faking emotional displays.

Deep acting (Actually experiencing the desired emotions)-

It requires the modification of an employee's inner feelings to express organizationally desired emotion. It resembles an antecedent-focused emotional regulation strategy (Groth et al., 2009), in which individuals attempt to modify how they perceive or interpret a situation to adjust their emotional response (Lam and Chen, 2012).

2.3 Customer Orientation-It has been studied at the organizational and individual worker levels .At the organizational level, it is an integral component of a market orientation (Deshpande et al., 1993; Narver and Slater, 1990). At the individual level it describes a personal resource of an employee and is defined as "an employee's tendency or predisposition to meet customer needs in an on-the-job context" (Brown et al., 2002)

2.4 Recognition (Accurate Self Awareness)- According to Steve Langhorn (2004) general manager individual emotional competencies performance depends on his ability to understand and recognize his own emotions.

2.5 Surface Acting -It is one of the form of emotional expression strategy wherein employees fake their true emotions. It involves an attempt to change what is privately felt (Hochschild, 1983).

2.6 Emotional Dissonance/ Job Strain-It refers to the differences arising out of the emotions displayed and the emotions genuinely felt. According to Morris and Feldman (1996), when there is a mismatch between genuinely felt and organizationally required emotions then greater control, skill, and attentive action is required. It is a work stressor and occurs widely among employees in frontline service jobs of the hospitality industry (Karatepe and Aleshinloye, 2009; Van Dijk and Kirk, 2007).

3. RESEARCH METHODOLOGY

3.1 Problem statement

The present study is to measure the emotional labor of the employees in the hotel industry.

3.2 Objective of the study

To identify the dimension related to emotional labor experienced by the employees in the hotel industry.

3.3 Research plan: Research Approach, Design, Method

Research Design	Research Methods	Sampling Plan			Instrument
		Sample Unit	Sample Size	Sampling Procedure	
Descriptive	Survey	Frontline employees	280	Non-probability Convenience	Undisguised structured

3.5 Output of Factor Analysis

Component	Item	Score	Dimension
1	I always know whether I am happy or not	.806	Emotional Intelligence
	I always know about my friends' emotions from their behavior	.810	
	I am a good observer of others' emotions	.796	
	I am sensitive to the feelings and emotions of others	.656	
	I have good understanding of emotions of people around me	.817	
	I always set goals for myself & try my best to achieve them	.608	
	I believe I am a competent person	.614	
	I am a self-motivated person	.620	
	I always encourage myself to try my best	.627	
	I am able to control my temper & handle difficulties rationally	.775	
	I am quite capable of controlling my own emotions	.812	
	I can always calm down quickly when I am very angry	.585	
	Try to actually experience the emotions that you must show to customers	-.767	
	Work hard to feel the emotions that you need to show to customers	-.910	
	Make an effort to actually feel the emotions that you need to display towards customer	-.926	
	I generally know what customers want before they ask.	.754	
	I am inclined to read the customer's body language to determine how much interaction to give.	.767	
	I enjoy delivering the intended service on time	.780	
	I find a great deal of satisfaction in completing tasks precisely for customers.	.822	
	I enjoy getting to know my customers personally	.680	
	I actually feel the emotions that I need to show to do my job well	.905	
2	Put on "mask" to display the emotions that manager demands.	.876	Emotional Labor Acting Strategies
	Put on an act in to deal with customers in an appropriate way	.772	
	Fake a good mood when interacting with customers	.867	
	Just pretend to have the emotions needed to display for job	.726	
	I fake the emotions I show when dealing with customers	-.766	
	I put on a mask to express the right emotions for my job	-.818	
	The emotions I show to customers match what I truly feel	-.744	
	I behave in a way that differs from how I really feel	-.822	
	I have to cover up my true feelings when dealing with customers	-.615	
	I show the same feelings to customers that I feel from inside	.823	
3	I have good control of my own emotions.	7.501	Customer Orientation
	I enjoy nurturing my customers.	.821	
	I take pleasure in making every customer feel special	.890	
	Every customer problem is important to me.	.898	

Component	Item	Score	Dimension
	I thrive on giving individual attention to each customer.	.899	
	I can easily anticipate customers needs	.867	
4	I have a good sense of why I have certain feelings most of the time	.741	Recognition-Accurate Self Assessment
	I have good understanding of my own emotions	.753	
	I really understand what I feel	.718	
5	Put on a “show” or “performance” when interacting with customers	.916	Surface Acting
6	My interactions with customers are very robotic(fake)	.791	Emotional Dissonance/ Job Strain
	I display emotions that I am not actually feeling	.853	

The above table shows 6 dimensions that were identified through factor analysis. They were emotional intelligence, emotional labor acting strategies, customer orientation, self awareness, surface acting and emotional dissonance or strain. These dimensions were further tested through mean test. The scores of which are mentioned below.

3.6 Summary: Dimensions and Mean

Sr. No.	Dimension	Mean Score
1	Emotional Intelligence	2.11
2	Emotional Labor Acting Strategies	2.60
3	Customer Orientation	1.73

4	Recognition (Accurate Self Assessment	1.84
5	Surface Acting	1.12
6	Emotional Dissonance/ Job Strain	3.99

From the above analysis it could be interpreted that employees indulge more in surface acting as their mean score is 1.12 which is less than all the dimensions. Hence employees do more of surface acting when interacting with hotel customers. The other dimension which leads to emotional labor is customer orientation as the mean score for it is 1.73 followed by employees self recognition as the score is 1.84.

Hypotheses Testing and Discussion

We have tested certain hypothesis using Mann Whitney test in terms of a demographic factor such as gender and the results are presented in the table below:

Hypotheses	Scores	Remark
Ho: There is no significant difference gender wise in the opinion, “Put on a “mask” to display the emotions that manager wants you to display”.	.014	As the value is less than 0.05, we reject the null hypotheses and conclude that there is a difference in the opinion, “Put on a “mask” to display the emotions that manager wants you to display” and gender.
Ho: There is no significant difference gender wise in the opinion, “Put on an act in order to deal with customers in an appropriate way”.	.000	As the value is less than 0.05, we reject the null hypotheses and conclude that there is a difference in the opinion, “Put on an act in order to deal with customers in an appropriate way” and gender.
Ho: There is no significant difference gender wise in the opinion, “Just pretend to have the emotions you need to display for your job”.	.019	We reject the null hypotheses and conclude that there is a difference in the opinion, “Just pretend to have the emotions you need to display for your job” and gender.

Gender differences

	Put on a “mask” to display the emotions that manager wants you to display		Put on an act in order to deal with customers in an appropriate way		Just pretend to have the emotions you need to display for your job	
Never	Male	Females	Male	Females	Male	Females

	51.1%	48.9 %	43.2%	56.8%	43.1%	56.9%
Rarely	60.0%	40.0%	62.8%	37.2%	66.7%	33.3%
Sometimes	65.1%	34.9%	100.0%	.0%	59.1%	40.9%
Very Often	100.0%	.0%	100.0%	.0%	62.3%	37.7%
Always	100.0%	.0%	100.0%	.0%	80.0%	20.0%

100% male employees always “put on the mask when displaying emotions that managers want them to display”. 80 % of the male employees “just pretend to have the emotions that they require for displaying in their job”. Male employees are more involved in surface acting than female employees.

4. DISCUSSIONS

In the service organizations particular hospitality industry the success and survival of its business depends on their employees. Hence employees are expected to show certain positive feelings towards customers. The results revealed that employees do more of surface acting. The hotel managers must create the situation where employees have to show less of surface acting. This could be done by giving them training and creating supportive system. Proper care must be taken while recruiting hotel staff so that surface acting is not required but deep acting. Hotel management must internalize the process so that employees exhibit deep acting when delivering services to the customers. As a personal resource customer orientation may serve as an antidote to the detrimental effects of job demands leading to delivery of superior customer service. Hotel administration must regulate the emotional display by employee's through periodic trainings to make them skilled in smiling in a truthful manner and for modification of their personal rage into public concern.

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A Review on Stabilizing the Manufacturing of SEEOM by Work Study

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Abstract: Work study is the techniques which is used to find the best way to do any activity. Work study is concept used to increase productivity of process by reducing different wastes like unnecessary moment, inventory, rework, over processing and transportation. It reduces work in progress. Work study is combination of method study and time study. This paper will be using both techniques which can optimize the productivity. In this paper work study technique is studied to stabilizing the production flow of SEEOM (Stored Energy Electrical Operating Mechanism) in industry. 5S is used to organize the workplace.

Keywords: Work Study, Time Study, Method Study, 5S

1. INTRODUCTION

SEEOM stands for Stored Energy Electrical Operating Mechanism. It is electrical operating device. It is mounted on the circuit breaker which are available in 3-Pole and 4-Pole variety of different rating ranging for 40A to 630A. SEEOM is used to operate Circuit Breaker from remote area. Mainly two type of SEEOM are assembled DN2 SEEOM and DN3 SEEOM. It is mainly used in large projects including marine application like navy.

2. LITERATURE SURVEY

Soumya R. Purohit et. al., 2015 explained how they were facing many problems in industry like overcrowded place, time waste in searching for tools, excessive stock, unwanted things, and Conditions go back to their old undesirable levels even after companywide implementation of 5S. 5S system is a starting point of all improvement efforts to drive out waste from the manufacturing process and ultimately improving a company's productivity by improving products and services and lowering costs.

Vipulkumar C. Patel et. al., 2014 used 5S methodology to solve the problems of a ceramic industry in India with the aim of increasing the efficiency of processes and eliminating wastes from the company. Their objectives was to reduce waste from process, one piece flow, maintaining quality level and reduce processing cost. By implementation of 5S and visual management system (GAMBA), there was increase in productivity, improvement in space utilization, employees safety, chances of error reduce and improved inventory management system, cleanness of machines and tools, improvement of the work environment, eliminating chances of accidents in the company. By implementing 5S, 12.91% sq. ft. space in the storage department was saved, as a result movement of men and material was also reduced.

A. Sai Nishanth Reddy et. al., 2016 were having assembly line balancing problem. Objective was to increase the productivity and re-design the layout of assembly line. They compare the actual assembly with new assembly by simulation in Arena software. They used time and motion study to calculate current time of assembly and to improve assembly. 363 seconds was reduce to 198 seconds to produce one unit of study lamp. The production line output increase from 69 units to 127 units. The line efficiency increased from 61.25% to 91.66%. The idle time decreased from 0.179 hours to 0.016 hours and the balance efficiency increased from 55% to 91%.

Ankit P. Vekariya et. al., 2015 studied assembly of diesel engine manufacturing unit. They found that there was no standard time for each operation and all work was done manually by workers and some operations sequences were not proper. By carrying Time Study in Industry all operations were breakdown into small activities and time for each activity was calculated. Process was also study by method study and new layout was proposed. Using MOST technique, proper operation and its sequence were found. By using time and method study material movement and flow of material has been improved. Efficiency of process was improved by 7.70% by time and motion study method and most analysis.

Dr. M. P. Singh et. al., 2016 did time study method which lead to reduction in process time, labor cost and production cost. Major problem were using old technology, manually finishing product, unfinished product from vendor. New technologies are used to reduced production cost, process time, cost and energy consumption after using method study. Improved layout and flow process chart and new devices are suggested using recorded observation and discussion with manager of the company.

Mr. Sujay Biswas et. al., 2016 states about excess material is removed manually after blow molding process. Due this problem they were not able to complete the work in time. Work-study is the most effective tool to increase productivity because it considers all the factors affecting productivity. By method study, most effective method of performing the job can be determined by layout improvement and by one piece flow. Work measurement will help to find time required to make a job in standard time at specific level of performance.

Mihir B Patel et. al., 2015 point out after studying several paper that work study techniques can be used to reduce the cycle time but also in various other departments in industries like inventory control, productivity, quality, labor work, at various machines in machine shop to get process variation etc.

Mr. Sujay Biswas et. al., 2016 emphasized on productivity improvement with the help of work study technique combined with motion and time study in the manufacturing enterprises. The work study technique is used by the manufacturing enterprises to reduce work in progress, inventories and waste of resources like man, machine, materials, space, etc. They only study work study technique and how to implement in industry. They conclude that work-study is the most effective tool to increase productivity because it easy to understand and can be used easily.

Ishwar Bhiradi et. al., 2014 worked on improving productivity of mixed model production system of a medium scale manufacturing industry using work measurement approaches. The work measurement of various activity of the work cycle has been taken. The work cycles were divided into small measurable work activities. These activities were recorded on the observation sheet. They also used time study and motion study to understand the various movement during process. Then all the non-value added activities has been removed. As a result there is 35% improvement in productivity.

Patange Vidyut Chandra 2013 applied work study technique. Here work study technique is studied along with time study and motion study. It gives the scopes of using work study technique in manufacturing industry. It explains the effect of work study technique on productivity, labor and workplace.

R. Hedman et. al., 2013 explained about using work study data in automated company to fully utilize the human resources. By this full capacity of the human and machine can used and productivity of company can be increased. If it is implemented in manufacturing models it will contribute to improve planning, control and execution of production. It will also assist and encourage production improvement initiatives.

Prof. S. B. Khedkar et. al., 2012 used 5S technique in a plastic molding company. Stepwise 5S was applied and all the unnecessary things where removed. Productivity increases, better space utilization, clean working area, standardization of process, PEEP application, etc can be achieved by 5S . By implementing 5S cost of production also decreases, decrease in sudden breakdown and increase in morale.

Mst. Murshida Khatun 2014 explained that there are varieties of garments produce in industry, so time study and method study is used to study the process. By using time study standard time required to make an individual garment is noted. Same way standard time for all different type of garments are find out using time study. Using motion study, motion of man, machine and material is studied and unwanted motion was eliminated. By making the time and motion study productivity can be maintain.

Shuang Lan et. al., 2009 used work study as they facing problems like bottleneck process and unbalance line. After the work study, different steps for improvement were taken, so the yield of A model lighting assembly line was increased from 9.97pcs to 12.19pcs. It reduced the operation time of the processes and eliminated the bottlenecks from processes. It enhanced the continuous production system. The number of workers was reduced from 21 to 18. The cost was reduced slightly.

Reda Tajini et. al., 2014 used work measurement technique. They used MTM and chrono-analysis to measure the work in two different ways. The chrono-analysis is an analytical method but it requires a lot of resources and time. The MTM is a fast method which is based on the time standards and the basic elements. The results obtained by both the methods were different. It is help full to identify number of workstations required in company.

Rishabh Mishra 2015 explained that how method study can be used for process improvement like work procedure and proper utilization of machine and material. It help to improve the current status of process and it reduces transportation and reducing worker's fatigue. By using method study productivity can be increased. After applying method study results weekly production increase from 560 to 588 per week.

H. Sabatini et. al., 2010 explained that how time study is a effective tool for detecting and reducing the cycle time losses in assembly line. Time study methodology helps us to calculate time for each activity in assembly. By using method study material handling can be reduce. Different lean can easily be identify. Time study and Method study help to eliminate lean waste from assembly line when used them proper other lean tools like 5S.

3. METHODOLOGY

3.1 Work study

“Work study is a generic term for those techniques, particularly method study and work measurement, which

are used in all its context and which lead systematically to the investigation of all the factors, which effect the efficiency and economy of the situation being reviewed in order to effect improvement.”

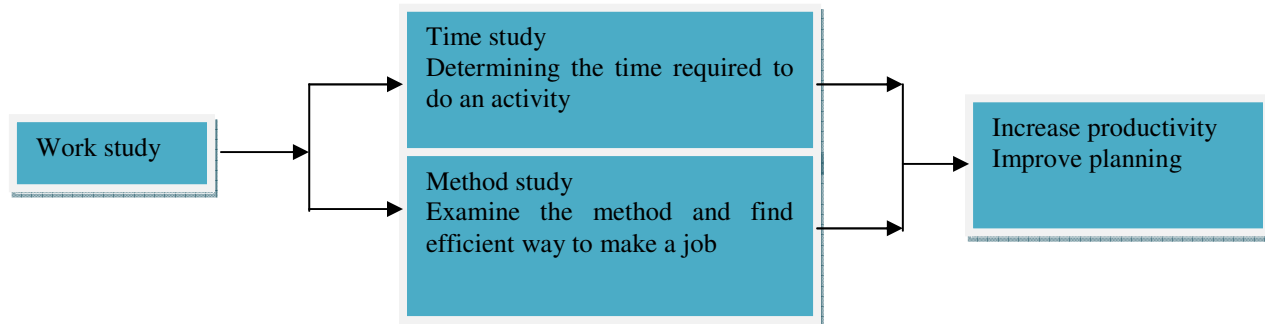


Fig: - 3.1 work study classification [Mr. Sujay Biswas et. al., 2016]

3.2 Time Study

Definition of time study is: “The art of observing and recording the time required to do each detailed element of an industrial activity/operation.”

Scope of Time Study

- Time required to make a job can be find out
- Comparison between different method can be done to find most efficient method by using time study
- Proper line balancing can be done
- It can help to analyze the process to reduce or eliminate unnecessary activities

3.3 Method study

Method Study may be defined as: “A procedure for examining the various activities associated with the problem which ensures a systematic, objective and critical evaluation of the existing factors and in addition and imaginative approach while developing improvements”.

Scope of Method Study:

- Quality standards
- Movement of material and tools
- Material to be used
- Cycle time

3.4 5S

‘5S’ is a workplace management methodology which helps to improve the working environment, human capabilities and thereby productivity. The word ‘5S’ represents the 5 discipline for maintaining visual workplace

1S Seiri (sorting):- classify wanted and unwanted things and removing unwanted things

2S Seiton (set in order):- it means set in such a way that there is neither extra motion nor any difficult in accessing the materials.

3S Seiso (shine):- always keep workplace and tools clean

4S Seiketsu (standardize):- define standard method for every process

5S Shitsuke (sustain):- Maintain consistency in the method of doing work

4. CONCLUSION

Work study includes time study and method study. work study is used find all factors affecting the production system. Work study help to identify and eliminate the waste like rework, work in progress, inventory, etc. By using method study various activities associated with the problem can be examine and ensures that work is done as per stated sequence. It will help to find most efficient way of doing work. Time study help measures the required time to perform the any activity. Standard time of each activity can be find out by time study. By using 5S, work place can proper be organized. Work study along with Time, Motion study and 5S can be very useful to stabilize the productivity of product, to calculate standard time of each process, reduce waste, organizing the workplace.

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Designing a Framework for Occupational Health and Safety as per Indian Context

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Abstract: Government is concerned about the safety of employee in a industries as its the top most priority for the sustainable development of the organisation as well as to create a friendly and healthy environment to work. Indian Government is implementing different laws and regulations concerning occupational safety and health and to secure the working environment and also implementing an adequate and appropriate system of inspection as the workers or the employees' safety is the top most priority for every industry. The purpose of this paper is to review research in the health effects and risks associated with the different industries like steel automobiles mining manufacturing sector and others like construction and to design a framework for these factors related to the occupational health and safety practice with the QFD tool. The important theme of this research is to propose a framework providing guidelines for the managers in policy formulation to improve safety performance as an essential concept of injury prevention social marketing

1. INTRODUCTION

To minimize the health hazards, organizations usually implement an occupational health and safety (OHS) policy authorized by the organization's top management clearly stating overall OHS objectives and demonstrating commitment to improve safety performance. The organizations establish, implement and maintain documented procedures for hazard identification, hazard/risk assessment and control of hazards/risks of activities. The methodology adopted for such activities is based on operational experience. However, identification of risks and remedial measures in procedural format is difficult to establish and varies with contextual environment.

2. BACKGROUND

Taking precautions against the risks and hazards in the workplace is one of the basic tasks of people with management responsibility. Efforts to provide safety in workplaces are not only significant for the health of workers but also inevitable managerial activities for economic and financial performance, productivity of the facility and the quality and stability of production (Fernández-Muñiz et. al. 2007). Furthermore, risk assessment is an essential and systematic process for assessing the impact, rate and the penalty of human activities on systems with hazardous characteristics and constitutes a needful tool for the safety policy of a company. The variety in risk analysis procedures is such that there are many suitable techniques for any situation and the choice has become more a matter of taste (Rouvroye and van den, 2002). A good number of research works have been done for assessing risk in construction industries by traditional tool like probabilistic risk analysis, fault tree

analysis, etc. based on historical data. The work by (Hauptmanns et al., 2005) based on fault tree theory, is the systematic procedure to perform a quantitative risk assessment for occupational accidents. According to (Faber and Stewart, 2003) risk is defined as the expected consequences associated with a given event.

3. RESEARCH METHODOLOGY

The questionnaire used in this study contained twenty eight items and the respondent needed to answer all the items using 1 to 5 Likert-type scale (1-strongly disagree and 5-strongly agree). The responses were collected from managers, safety officers and workers of different departments (both private and public) across the organisation through e-mail/postal/personal contacts. The perceptions on twenty eight items from respondents related to occupational health and safety in the industry types were compiled.

3.1. Result Analysis

Fifty useful responses were tested to examine the validity and reliability of the scale so as to obtain a quantitative and statistically proven identification of the responses. The test for quantitative variable was conducted by factor analysis on 50 responses using the principal component method followed by varimax rotation to ensure that the variables are important and suitable for the model using Minitab 15.0. Twenty two items were categorized under nine social factors constituting various variables for proposed instrument to measure the relation between occupational safety management and firm performance as perceived by safety officers and workers. These nine social factors are defined as Preventive procedure, OHS training, Risk management, Work practices, Periodic plans, Continuous

improvement, Injury avoidance, Emergency plans and Health care. The items that failed to get loaded more than 0.5 were not considered for further analysis. This was true for refer to items 5, 6, 8, 10, 21, and 22. Percentage of total variance explained was found to be 75% which is an

acceptable value for the principal component varimax rotated factor loading procedure. The internal consistency of the actual survey data were tested by computing the Chronbach's Alpha (α). The factor loadings are shown in Table.1.

TABLE 1: Factor Loading Score

Factor	Item No	F1	F2	F3	F4	F5	F6	F7	F8	F9	Cronbach's Alpha
Preventive Procedures	2	.877									.825
	3	.557									
	4	.593									
	13	.892									
OHS Training	9		.626								.782
	10		.683								
	11		.787								
	12		.697								
Risk Management	5			.614							.516
	6			.665							
	7			.578							
	18			.627							
Work Practices	8				.754						.714
	21				.648						
Periodic Plans	19					.748					.760
	28					.774					
Continuous Improvements	7						.517				.656
	15						.853				
Injury Avoidance	16							.613			.747
	17							.820			
Emergency Plan	14								.843		.842
Health Care	20									.888	.788

After getting seven important parameters/items for the improvement of policies of Occupational health and safety by interview with experts, QFD was applied to identify system design requirements for occupational health and safety is studied. Steps of QFD are:

- Customer needs (What's): A structured list of requirements derived from expert's feedback listed in figure 1 left side.
- Design requirements (How's): A structured set of relevant and measurable services/characteristics which are required for fulfilling what are mentioned in figure 1 topside.
- Planning matrix (left matrix): Gives customer/expert perceptions observed in surveys. It includes the relative importance of requirements

- Interrelationship matrix (center matrix): Gives the expert's perceptions of interrelationships between design requirements and customer needs. An appropriate scale is applied and illustrated using symbols or figures. Filling this portion of the matrix involves discussions.
- Design correlation (top) matrix: Used to identify where design requirements support or impede each other in the system or product design.

$$\text{Customer ratings} = Z_i + \frac{1}{n-1} \sum_{j=1}^n (B_{ij} Z_j) \quad (1)$$

B_{ij} is i^{th} initial customer rating and Z_j denote the relationship between customer need and customer rating respectively

n number of customer need
 B_{ij} [B_{1ij} , B_{2ij}].

The individual rating for each design requirement is obtained from the center matrix using the following relation: Design requirement = $\sum_j^n (A_{ij}, X_j)$ (2) Where A_{ij} and X_j denote the relative importance of the i^{th} characteristics with respect to the j^{th} customer need in the relationship matrix and the importance of j^{th} customer needs (customer ratings) and n is the number of customer needs. Table.4 shows Employee requirements and Table.5 explains design requirement. Table.6 shows the symbols used in QFD. Figure1 shows QFD HOQ.

TABLE 4: Employee Requirements Table

1	Preventive measure
2	Emergencies plan
3	Injury avoidance
4	Health plan
5	OHS training
6	Periodic plan
7	Risk Management

TABLE 5: Design Requirement

1	Safety training programs are conducted in the organization on regular basis
2	Instruction manuals being followed before executing any hazardous job activity
3	Immediate medical facilities are provided for personal injuries

4	Alarms/beeping sound/alarming light and emergency lights work effectively when a crisis situation arises
5	A Safety equipment's are supplied by the organization to avoid accidents
6	The company readily provides health subsidies when accidents occur within the workplace
7	The employees works in healthy and safety condition
8	Regular auditing is done by OHS
9	Company undertakes a stress risk assessment in the workplace

TABLE 6. Symbols of QFD

0.8	Strong	0
0.6	Moderate	Θ
0.4	Weak	Δ
0.2	Very weak	

A QFD matrix was prepared, and the respondents were asked to assign numeric relative importance scores to the various customer requirements, from the lowest to the highest, on a scale from 1 to 9. They were also asked to express, in numeric values, the strong-moderate-weak relationship between what's and the How's as .2, .4, .6, and .8 with symbols. After the responses were collected, scores for each of the columns was computed. The design requirements are prioritised as per their importance of design requirement.

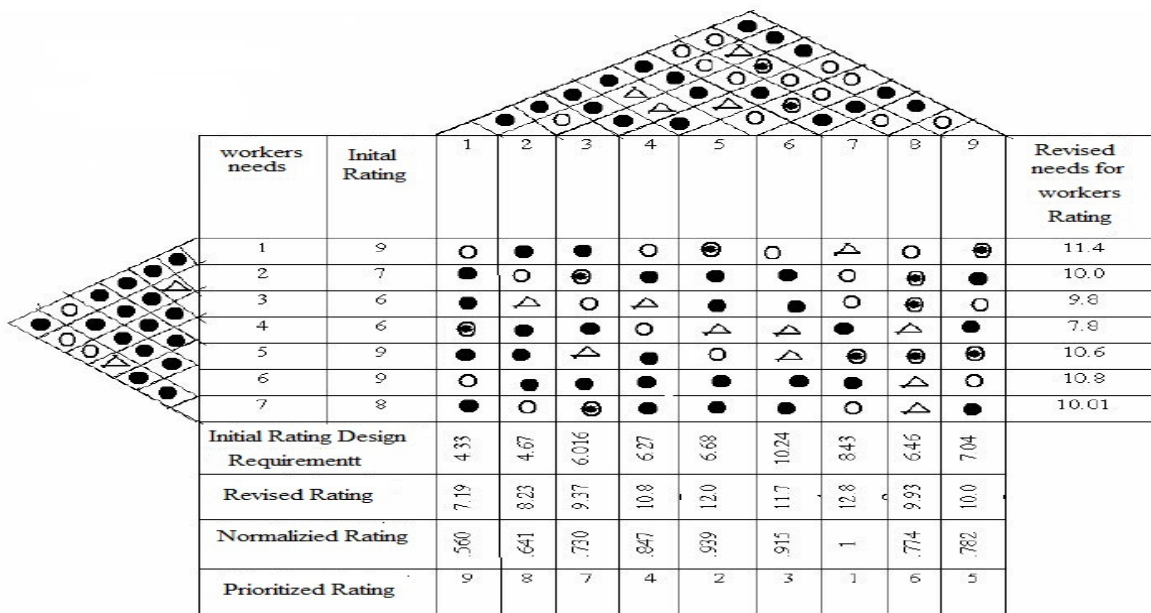


Fig. 1. House of Quality

4. RESULT AND DISCUSSION

As OHS is a sensitive issue, the industries are reluctant to share the accident data at least in Indian environment to gain insight into the problem and propose corrective measures. Because of paucity of field data, the study undertakes a questionnaire survey to assess the safety culture in industrial settings. Although the survey uses many safety items (or characteristics), it finds that the items and number of items widely differ across the types of industries, size and location of organizations.

5. CONCLUSION

The instrument developed is useful for improving morale of the workers and their satisfaction in regard to safety issues. The instrument has been tested using statistical tool and can be used for comparative evaluation of safety practices within and/or among organizations. Using the instrument, comparison of various industrial settings has been made using discriminate analysis. An instrument has been proposed to assess OHS practices in Thermal Power Plant

which are characterized by disorganized and unsafe work environment. Although internal guidelines and Government legislation is being practised in these industries, the work practices seems to be below average.

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Optimization of Resources through Automation

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Abstract: In today's competitive world productivity improvement is one of the most important initiatives to keep us ahead of competition.

With the increasing competition and change in economic scenario of country surviving & growing in steel sector is becoming tough & tougher. Cost optimization, value engineering, productivity improvement, quality improvement and time management has become the vital tools for the survival, progress and to become an EVA positive organization.

- In this Long product Mill there are three separate Control pulpits as:
- CP1 for controlling billet feeding to the furnace
- CP2 for controlling billet feeding to the MILL (out from furnace)

CP3 for billet movement in different stands of Mill for formation of Wire Rod.

Being located at three different places and being managed by 3 teams there were many incidences of coordination gaps which resulted in chopping off the Billet which was a huge financial loss. Moreover the Mill had to be made down for correction which was again a big opportunity loss.

Another aspect was, in this era of automation and mechanization the manning for this section was a concern. Moreover as per the company's norms relievers in each pulpits were also given separately which was ultimately lowering the productivity and affecting the bottom line of the Company.

This paper deals with the approaches taken in the Long product Mill to identify and resolve the issues related to better coordination of billet movement, Manning optimization and automating the whole system. After a long study and research a decision has been taken for merger of all three pulpits into ONE. Different Industrial engineering Principles & techniques were used in the entire study like work measurement, Facility Planning & Layout Design.

For this idea implementation there were few factors that proved to be hurdle in implementing the ideas identified which included both Technical aspect as well as IR issues. After proper approval the idea of Merging of three pulpits is on its way of implementation. It is proposed to be implemented and functional by 2019 March.

1. INTRODUCTION

Any organization is a combination of many small units that unite and work to achieve a goal together. In a steel plant also there are many interconnected units/plants, starting from planning till dispatch. So it's very important that every unit is so productive enough that overall Plant/company is ahead in the industry's productivity race. In this competitive era we should focus of each and every bit of either reducing waste or improving current practices so that loss can be minimized & profits can be maximized.

2. PLANT DETAILS

- Installed in 1987
- Built by M/s Davy-Mckee, U.K
- Mill consists of
 - Billet processing facilities in Billet yard,
 - Reheating furnace,

- Roughing Mill,
- Intermediate Mill,
- Pre Finishing Mill & Non –Twisting Mill

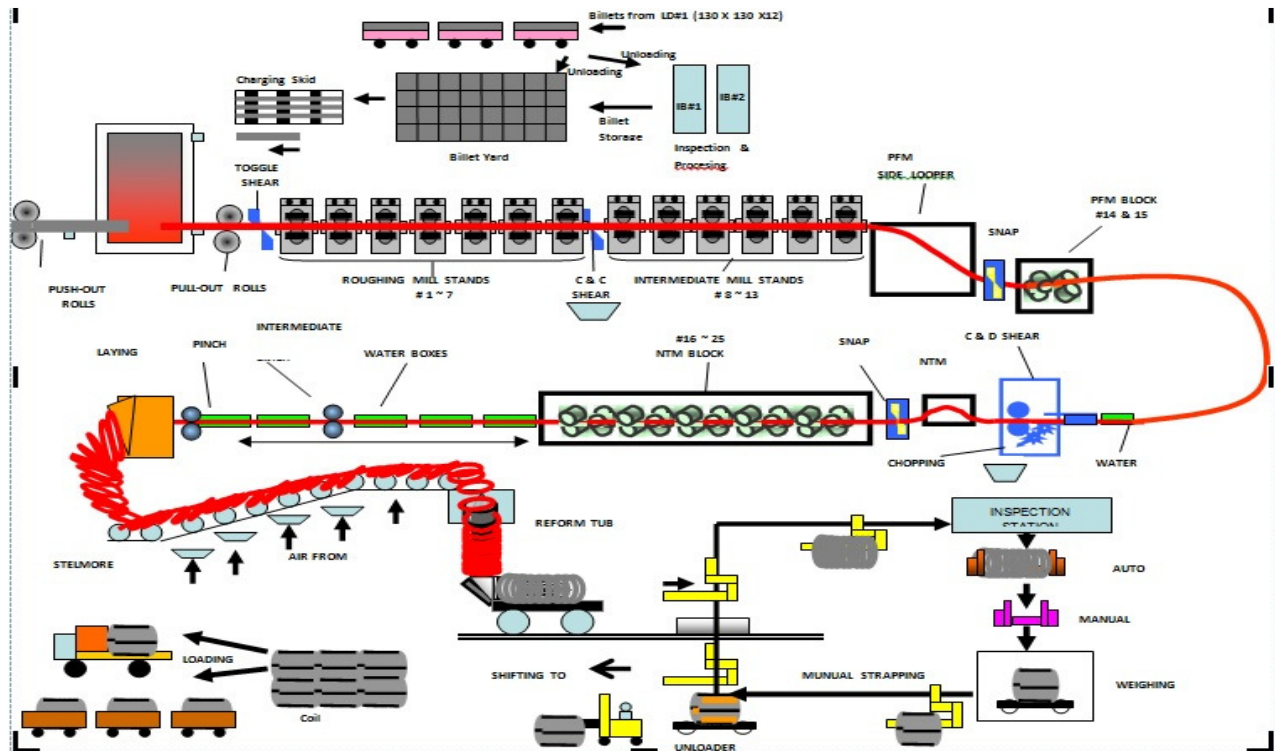
- Plant capacity: 0.42MTPA
- Facility of online inspection by Process Control is installed with an express lab for quick decisions.
- The Mill has been installed with Profile gauge, Flaw detector, Laying head with front end orientation and Ring distributor

3. PRODUCT RANGE OF THE LP MILL

- The mill is designed to produce 5.5 mm to 20 mm dia. rounds and 8, 10 & 12 mm diameter Rebar
- This mill can produce following quality of wire rods
 - Low Carbon

- High Carbon
- Pre-stressed Concrete
- Electrode quality
- Cold heading quality
- Ball bearing
- Cable armored quality
- High yield strength rebar
- This mill converts the billets into plain wire rods in sizes 5.5mm to 13.0mm and re-bars used in construction segment in sizes 8.0 – 10.0mm. This is done by innovative & analytical approach based improvements in existing Processes/Products and help in maintaining the cost effectiveness

4. LAYOUT OF MILL



5. FORMATION OF WIRE ROD FROM BILLET

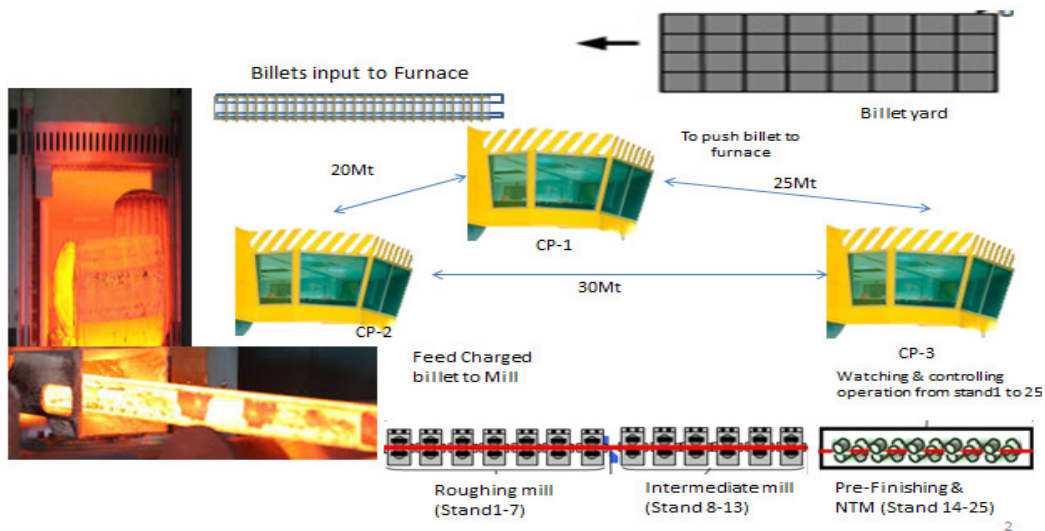
- This process starts from Billet inspection. After the inspection billets are placed on the Charging grid by Crane.
- One by one (at an interval of ~90 sec) billets are pushed in Furnace and this activity is controlled and monitored at CP1.
- Charged billets once out from the furnace are sent to Mill. This billet supply to mill is controlled and monitored at CP2.
- Charged billets are passed through different stands of Mill for the formation of Wire rod. This whole process is controlled and monitored at CP3.
- Once wire rod is formed it is passed through Stelmor convener and sent to OS6 (Finishing section)

- The Finishing section then takes care of coil inspection & testing then binding.
- After this Shipping section does the loading and dispatch activity.

6. CURRENT ISSUES AT MILL

The three activities: Pushing billet to Furnace, Feeding charged billet to Mill & Formation of Wire rod from Billet are the most critical (inter-connected) activities.

But monitoring these three at three locations was creating problems. The CP1 operator has no visibility of what is happening in Mill and same with CP2 & CP3, they had no visibility of Billets pushing to furnace. Biggest problem was the coordination gap!



Many times it happens that some sudden problem happen in Mill so the mill had to be stopped. But by the time this message was passed to the CP1 operator he already inserted a billet to Furnace. So there was no other option rather than chopping off the billet. This was a huge Loss.

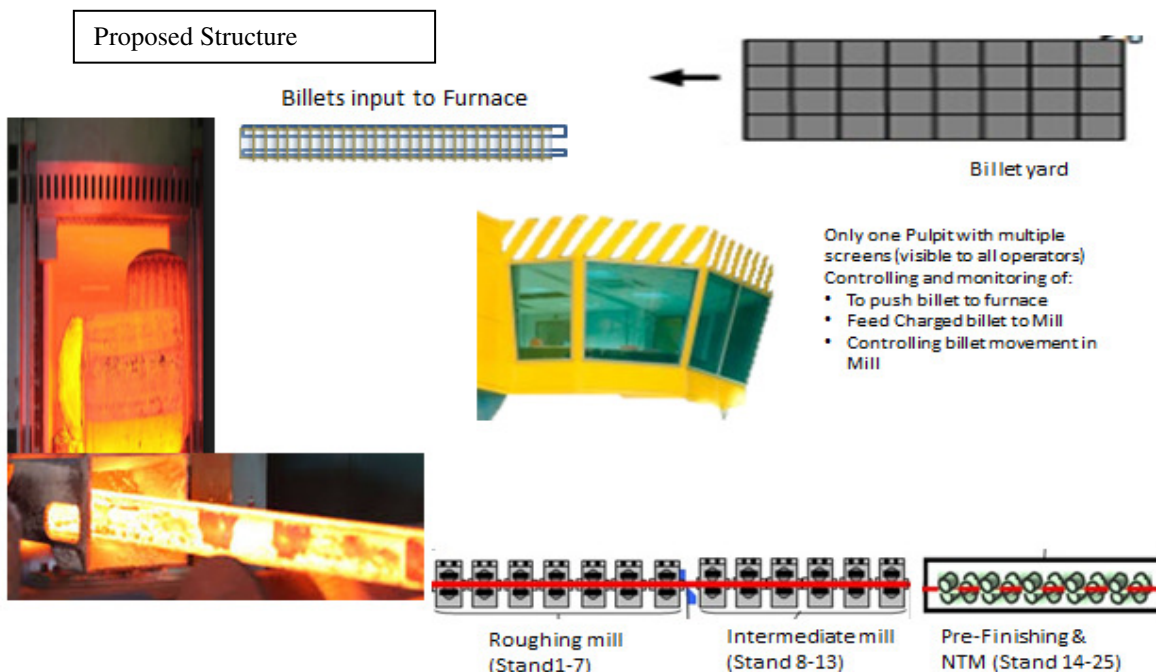
Area	Working Force	Relievers	Total
CP1	1/shift	1/shift	2/shift
CP2	1/shift	1/shift	2/shift
CP3	2/shift	1/shift	3/shift
Total /Shift			7/shift

Another perspective of this issue was the Manning of Mill. The manning was done pulpits wise and also as per the company norms relievers to all operators were given.

In this era of Automation and Mechanization operating a Mill with so many people was a bottleneck to Productivity.

7. PROPOSED SOLUTION

After a detailed study from all perspectives better coordination of billet movement, Manning optimization and automating the whole system. After a long study and research a decision has been taken for merger of all three pulpits into ONE. Different Industrial engineering Principles & techniques were used in the entire study like work measurement, Facility Planning & Layout Design.



8. IMPLEMENTATION OF PROPOSED CONTROL PULPIT STRUCTURE

- The first step towards this was preparation of plan and budget.
- Approval for capital investment was taken from higher Authorities
- Different agencies were invited for study of plant and give quotation for formation of new pulpits.
- Most suitable vendor was selected and order for new pulpit was placed.
- By March 2018 the ordered pulpit is expected to be delivered which will be installed during next annual major shutdown of plant.

9. CHALLENGES

The major challenge what is visible now is the IR issue. Being an old mill most of the employees are 40+ years of age and for them adopting a new work practice will be tough.

There will be a reduction of workforce as with the merger of pulpit the roles will be merged so instead of current 7/shift we would only need 4/shift for Mill operation. So this reduction implementation has to go through some Union discussion and finalization.

10. CONCLUSION & BENEFITS

For the successful implementation of a proposed structure, the organization's objectives, principles undertaken in designing of the organization structure & HR issues need to be carefully considered.

There will be multiple benefits after this new pulpit installation

1. Saving of billet wastage
2. Opportunity loss reduction: As the mill has to be made down for chopping off the charged billet
3. Manpower cost reduction

Review of Habits of Mind Using Teaching Pedagogies for Analyzing Thinking Strategies in Engineering Education Classroom Teaching to Improve its Performance

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Abstract: Deficiencies in engineering education have been exhaustively exemplified in past few years. Higher education is becoming a major driver of economic competitiveness in an increasingly knowledge-driven global economy. The focus of engineering education is shifted in last decade around designing course with outcome based learning and employability for students. The contemporary attention of higher education institutions is weighed on the basis of its national and international rankings. And these comparisons tend to overemphasize research, using research performance as a yardstick of institutional value. If these processes fail to address the quality of teaching, it is in part because measuring teaching quality is challenging. With this comprehensive wish list it will be highly difficult to design engineering curriculum so that the average student can complete his graduation in four years. The present paper is an attempt to summarize bridge gap through design of effective teaching pedagogies in order to provide engineering solution to real world problems.

Keywords: Classroom Teaching, Habits of Minds, Engineering, Pedagogy

1. INTRODUCTION

If one could try to define engineering or what an engineer is, we will all come up with similar answers as ‘engineering is the application of science’ or ‘the use of science and mathematics for solving technical problems’, or ‘Engineering is the science, skill, and profession of acquiring and applying scientific, economic, social, and practical knowledge, in order to design and also build structures, machines, devices, systems, materials and processes’ and anyone who practices engineering is called an engineer.

The US Accreditation Board for Engineering and Technology (ABET) has also similar kind of definition: ‘The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property’.

Plato (2013) [17] has established relationship of engineering with other disciplines as illustrated in Figure 1.



Fig. 1. Engineering is applying science for creating our physical world.

2. SURVEY:(FOR CLASSROOM TEACHING)

This paper surveys few instructional summarize methods and pedagogical techniques that extends engineering theories beyond the realms of classroom teaching.

2.1 Formulate, publish and communicate instructional objectives clearly: [1–10]

The board of studies brain storms to formulate the course objectives, which in later is published by course teachers to communicate it effectively to the students.

This way an instructor items the list of instructional objectives with detrimental goal. And the measurement

criteria should be included for defining statement in following manner.

Bill Lucas et.al (2016) identified six Engineering Habits of Mind (EHoM) to cultivate them in class rooms using four pedagogies.

Claxton et. al, (2016) suggested ways of finding, developing and improving which causes confusions for educating employable engineers.

Heckman & Kautz, et.al (2012) investigated the individual potential for enhancing the individual success in the market for long term through soft skills.

Example: Course Objective for Engineering Metrology:

Students are expected to-

1. Select suitable instrument/gauge/method of inspection for determining geometrical and dimensional measurements.
2. Calibrate measuring instruments and also design inspection gauges.

Course Outcomes for Engineering Metrology:

Students should be able to-

1. Select measuring instrument, carry out data collection and data analysis.
2. Design gauges required for inspection purpose.

2.2 Inductive Vs Deductive approaches of Teaching:

These approaches of teaching works exactly in contrast to each other. In inductive approach students generalize theories based on common elements of collected information. Whereas, in deductive approach students collect information based on general theories. This contrast in approach is explained in fine manner with following figures:

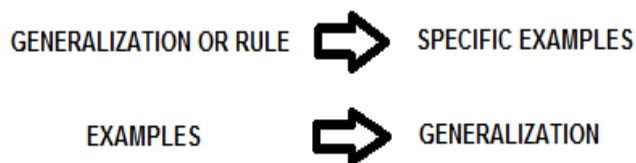


Fig. 2. Contrast between Inductive and Deductive approaches of teaching

Example:

Case-I: A group of students assigned to jot down the ideas based on topics covered during classroom teaching for design of pipes.

Case-II: Another group of students assigned to design piping system for boy's hostel from central tank.

The very common and famous inductive teaching pedagogical tool in higher education is project based learning (PBL). Wherein, the group of students built their project around real world problems. Many researchers [11-13] have highlighted this as an effective tool in the field of science and technology.

2.3 Inculcating culture of Active Learning in the Classroom through Cooperative Learning Approach:

Cooperative learning approach is rapidly growing instructional method in engineering education due to its effectiveness [14-16].

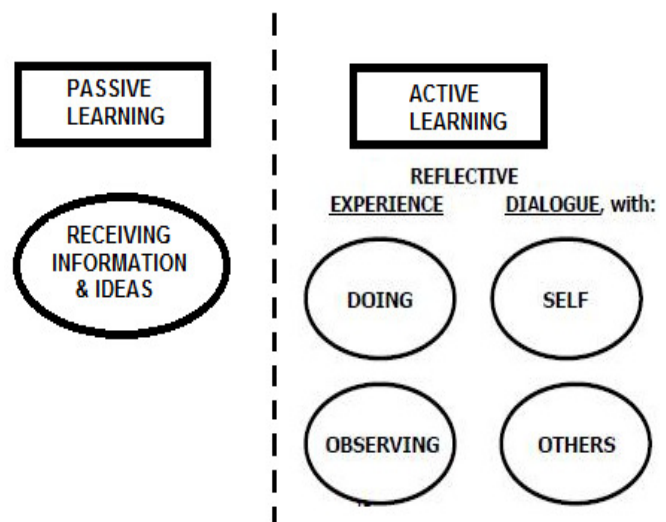


Fig. 3. Inculcating Cooperative Learning in the Classroom

Example: Assigning groups for completing laboratory reports, projects, and assignments in courses.

3. LITERATURE SURVEY:(FOR TEACHERS)

This section of paper deals with class room habits and flow of information those are made by teacher during class room teaching.

Wood and Runger et. al, (2016) demonstrated effectively the class room behaviors of students are helpful for individual progress and their workplace.

Lally and Gardner et. al, (2013) suggested to trigger individual through reward for class room responses. This key repetitive habitual action encourages class room habits.

Bloom and colleagues et. al (1984) defined six levels of instructional objectives as per following manner:

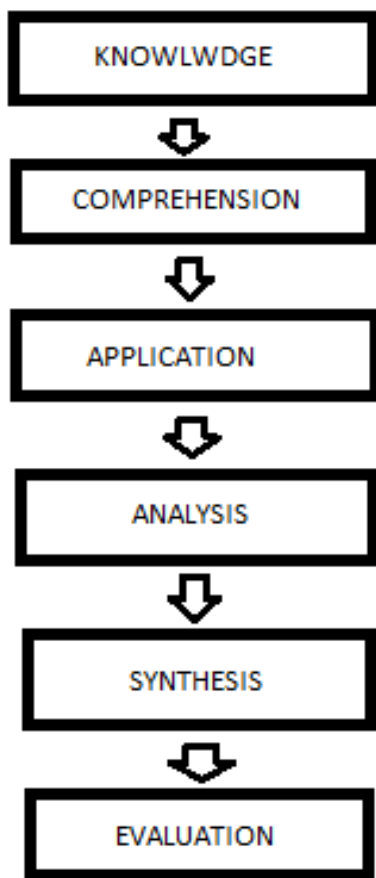


Fig. 4. Six levels of instructional objectives

The levels 1–3 are commonly known as lower-level skills and levels 4–6 are higher-level skills. UG level skills focus on 1-3 level whereas, as per ABET engineering accreditation criteria involves higher criteria skills.

4. CONCLUSION

This paper is an attempt to identify budding engineer's habits of mind to know more about their thinking strategies during classroom teaching. These habits of mind can be strongly planned with effective class room pedagogies to solve real world engineering problems.

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Determinants of Employee Satisfaction in EPC Companies of Oil Industry in Middle East

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Abstract: The aim of this paper is to find out the Determinants of Employee Satisfaction in EPC companies that are engaged in Oil and Gas Industry in Middle East. The current trend of low Oil prices have forced EPC Companies in Oil Industry to restructure their sizes resulting in number of persons losing their jobs. This has resulted in low level of Employee Satisfaction. A satisfied employee will definitely be inclined to put his best show which naturally would enhance the chances of a company in achieving its various business parameters. Since EPC companies work on time bound projects and with stiff competition, this study assumes importance. Selected Sample from EPC companies in Oil Industry was surveyed. The results proved that the current Employee Satisfaction level is lower than the Middle East standard as well as Global standard. The Determinants of Employee Satisfaction is also found out.

Keywords: Employee Satisfaction, Oil and Gas Industry, Middle East

1. INTRODUCTION

Satisfied Employees are vital for the success and performance of an Organization. According to Rust et. al, (1996), Employee turnover is inversely proportional to Employee satisfaction; i.e. increase in Employee Satisfaction will lead to reduction in Employee turnover and vice-versa. The Latest study conducted by Gulf Business (published on 3.6.2015) states that in UAE around 53% of the employees are having low level of satisfaction.

The EPC Companies work on a tight budget and time schedule. If they fail to complete the project in time, they will have to pay liquidated damage (LD) or penalty which generally goes up to 10% of the contract value. Further, they also will incur additional cost due to extended stay. This will affect the companies' performance and considerable negative effect in the bottom line. Each and every project handled by EPC companies is unique in nature. The persons involved are required to deliver their portion of work till completion of the project. If some employee leaves at middle of the project, the replacement employee will take considerable time to understand the project and to start delivering his / her duties. This will affect the time schedule of the project.

A study conducted by Abubakr M. Suliman Hanan et.al., (2011) concludes that recruitment and retaining of employees has become one of the main problems faced by Middle East Countries. They state that the staff turnover costs in organizations operating in UAE costs about AED 9.9 billion a year. The study confirms that the current organizational climate is discouraging and it negatively

affects employee satisfaction level. This in turn may hasten employee turnover.

Elisa et al., (2001), in their study state that costs to the organization for an expatriate employee returning home prematurely have been estimated to range between USD 100, 000 and USD 500, 000, and nearly 20% left their organization only to work for a competitor after returning home.

The EPC Companies in Oil Industry work on a tight timeline and budget. Due to the reduced level of Employee Satisfaction, employee turnover shall increase resulting in:

- Revenue loss for the companies due to replacement cost
- Revenue loss due to companies' extended stay in the project.
- Revenue loss in the form of Liquidated damages and Penalties levied by Clients
- Revenue loss due to less productivity from the existing dissatisfied employees
- Non Revenue Loss due loss of reputation / goodwill in the market
- Losing of future contracts due to above factors.

Hence the study of Employee Satisfaction in EPC Companies of Oil Industry in Middle East assumes great importance. The paper is aimed at finding the determinants of Employee Satisfaction of EPC Companies engaged in Oil and Gas Industry in Middle East.

2. LITERATURE REVIEW - EMPLOYEE SATISFACTION

A detailed Review on existing Literature was conducted to find out the determinant of employee satisfaction. Bakr Ahmed (2008) states that diversity is positive factor which leads the firms to be healthy and it creates competitive advantages for firms. According to Jasna et al (2011), the very important characteristics of an organizational support favorable to employee satisfaction include giving employees discretion on work, giving a patient ear to his employees' suggestions/grievances, rewards, training, management support, trust, free intra-organizational boundaries, commitment and involvement in their personal welfare.

Muhammad Eshan Malik et al. (2011) splits his findings into two parts - one on the employee's retention and the second one on employees turnover rate - he concludes that while organizational culture, promotions, training practices and hiring of the personnel have directly influence on employee's retention; the organizational goals, its missions (in giving importance to employees' suggestions), rewards given to employees, compensations (provided to employees' well being) and recognitions (highlighting their achievements) positively decrease turnover rate of the employees.

John Sutherland's (2013) study emphasizes that personal characteristics such as gender, age and education and also to job characteristics such as hours worked, training provided, promotion prospects, and establishment size play significant role in arriving at the job satisfaction. Benjamin Artz, (2010), argues that job satisfaction is inversely related to job absenteeism, turnover and directly related to output. Aysit Tansel and Saziye Gazioglu conducted a study in 2013 titled "Management-Employee Relations, Firm Size and Job Satisfaction". They found out that a good relationship between management and employee is necessary for a satisfactory organizational performance of an organization and for its human resources to feel that they are being effectively engaged.

Carolyn Stringer et. al., (2011), find that intrinsic motivation and satisfaction with one's pay have a direct bearing on employee satisfaction, whereas extrinsic motivation has a negative association with employee satisfaction. Aon Hewitt (2014) observes that Middle Eastern organizations have the tendency to push their growth and profitability targets further and putting the economic crisis in their back yard without the thought that it imperative for an organization to retain the required talent to achieve their ambitious goals. Yousef (1998) opines that the employees (expatriate) in Saudi Arabia are not pleased with their job security.

Kuehn et al. (2002) found that Omani employees reported relatively high levels of both satisfaction and commitment

as compared to expatriate workers, particularly in the private sectors. Alizee B Avril et al., (2007), in their study disclose that main reason for an expatriate to fail in his / her assignment is the incapability of the expatriate's spouse to get adjusted in his / her new surroundings. The expatriate has a sense of belonging at the work place where as the spouse often struggles with feelings of alienation. Okpara et. al., (2011), summarized that from 10% to 80% of expatriate employees who were sent on foreign assignments were returning home before completion of their assignment. This is costing multinational enterprises (MNEs) in the range of U.S.\$ 40, 000 to U.S.\$ 1 million for each failed assignment. The main reason for expatriates' failure is identified as their incapability to adapt themselves to the host-country's culture.

3. THE PRAPOSED METHODOLOGY TO FIND OUT THE DETERMINANTS OF EMPLOYEE SATISFACTION FOR EPC EMPLOYEES WORKING IN OIL INDUSTRY IN MIDDLE EAST

The Research Methodology proposed for the Study

Objective	To find out the determinants of Employee Satisfaction in EPC Companies that are engaged in Oil and Gas Industry in Middle East
Research Design	Descriptive Research Study
Observational Design	1. Variable Identification through Literature Review (Various Facets of Employee Satisfaction) 2. Preparation of questions asking the respondents to list the factors contributing to improve satisfaction 3. Pilot testing of the Questionnaire 4. Administering the Questionnaire to the selected Sample 5. Conducting Structured Interviews with top level management of selected EPC Companies
Sampling Design	Employees' Portion of Sample Stratified Proportional Sampling (strata based on Large, Medium and Small EPC Companies) to select the number of companies in each strata. Within each company the sample size was decided which was proportionate to their Middle East staff Strength. The sample selection for the decided strength within the company was based on disproportionate stratified sampling Sample size estimated based on Taro Yamane's formula was 100 and Sample size Obtained is 93

Objective	To find out the determinants of Employee Satisfaction in EPC Companies that are engaged in Oil and Gas Industry in Middle East
	Employer's Portion of Sample The EPC companies were stratified as Large, Medium and Small. Since the Employees of Large Companies will have good satisfaction level, they have not been selected in the sample. One Medium size Company and Two Small size Companies were selected. Top Level Employees of these Companies were interviewed to get their inputs on changes that are needed to improve Employee Satisfaction
Data Analysis	Descriptive Statistics. Tabulation of results by combining the responses from Employees and Employers

4. EMPIRICAL STUDY

In this section, an empirical study is presented in which the determinants of Employee Satisfaction of EPC Companies that are engaged in Oil and Gas Industry in Middle East was found out. 93 Respondents provided suggestions

containing 279 suggestions in total. These were grouped under 21 parameters. The following are the improvements suggested by the Employees for enhancing Employee Satisfaction:

4.1 Problem Description

There is a huge Business loss due to Employee turnover. The Employee replacement cost also amounts to loss for the organization. Addin to the above, the EPC companies face problems such as tight work schedule and stiff competition. Success can be achieved by them only if they improve their edfficiency. One of the means to improve efficiency is retaining talent and motivating them to deliver their best. This can be possible with improved Employee Satisfaction. The study is aimed to find out the determinants of Employee Satisfaction in EPC Companies that are engaged in Oil and Gas Industry in Middle East.

4.2 Findings of the Study

The findings of the study revealed that the current level of Employee Satisfaction of EPC Employees is much lower at 5.7 when measured on a 10 point scale compared to Global Standard of 7.2

The chart below provides changes that are suggested by respondants to improve Satisfaction level:

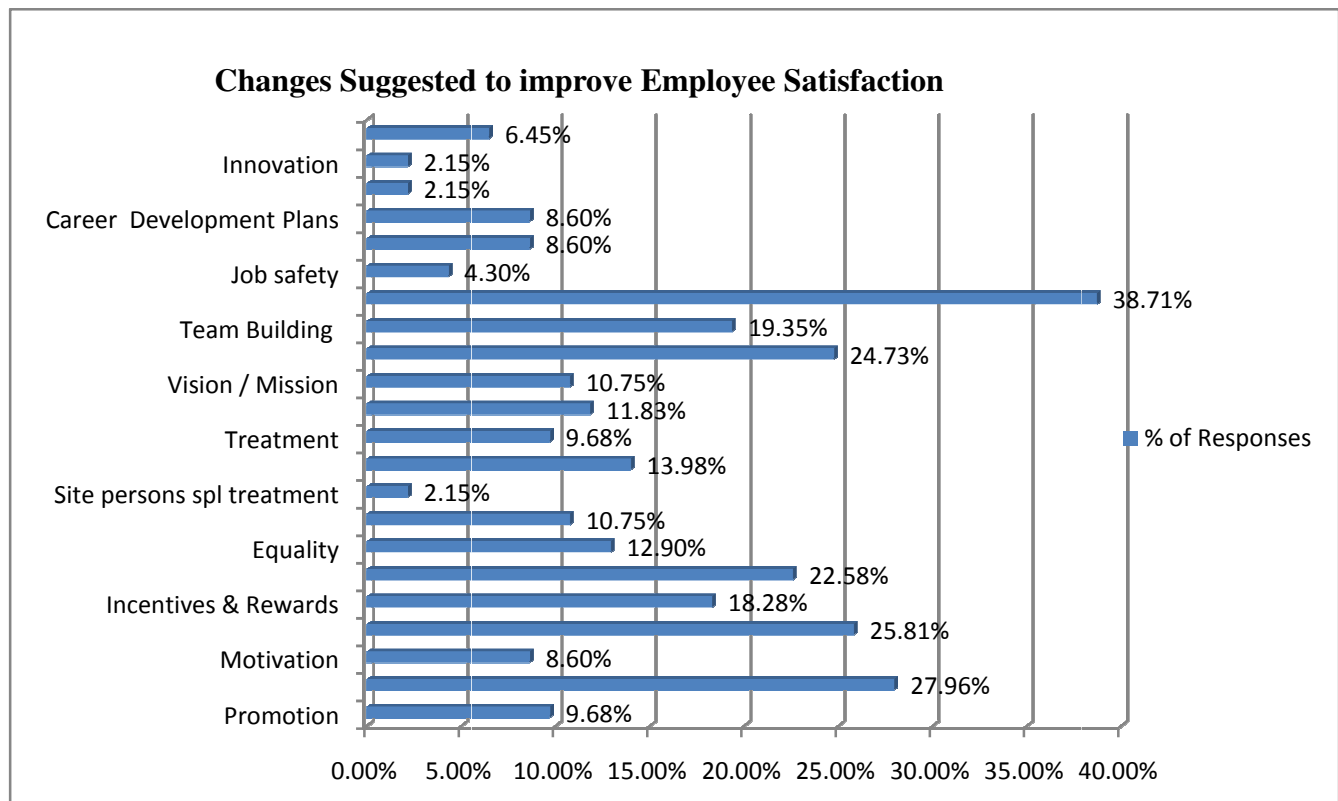


Fig. 1. Changes Suggested to improve Employee Satisfaction

38.71% Respondents felt that Training is very important for employee satisfaction followed by Salary increase (27.96%) and closely followed by Appraisal & feedback (25.81%), Fringe benefits (24.73%), working hours (22.58%) and Team Building (19.35%). Incentives & Rewards (18.28%), Communication (13.98%), Equality (12.9%), Recognition (11.83%), Clarity of vision / mission (10.75%), Appreciation (10.75%) have been placed at a correspondingly lower level.

It is interesting to note that Employees have given very less importance to Promotion (9.68%), Good treatment (9.68%), Motivation (8.6%), Good supervision (8.6%) and career development plans (8.68%). All other heads (4 parameters) have been established as having least importance.

The following table provides the clear view of the respondent's suggestions:

% of Respondents Suggesting improvement factors	Suggested Factors for improving Employee Satisfaction
More than 20%	Training, Salary Increase, Appraisal & Feedback, Fringe benefits and Reduced working hours
11% to 20%	Team Building, Incentives and rewards, communication, Equality, Recognition, Clarity of Vision / mission and Appreciation
Less than 10%	Freedom of work, innovation, career development, good supervision, role clarity, job security, Motivation, Promotion, Special treatment for Project persons

5. DISCUSSION

Since there is a huge cost involved in the separation, recruitment and replacement of employees, it is profitable for the organizations to retain the talent. Further, the EPC Companies in Oil Industry engage in projects which are unique in nature. In such circumstances, the employee engaged in the project does some only-one-of-its-kind type of job unlike a common type of job done by employees of other normal industry. A lot of safety related trainings are involved in the placement of employees in EPC Oil industry such as Safety Induction, H2S training, TBOSIET, First aid etc. in addition to special medical tests. These training and tests are very costly and time consuming. So, replacing an Employee of EPC Company in Oil Industry will not only be a costlier affair but also time consuming. Since these companies will be working on a tight timeline, the delay in replacement (of employee) will lead to project delay as well as loss to the company due to extended stay. This will also create a loss to the end user. Considering the above, it is very much evident that Employee Satisfaction is very important in EPC, Oil Industry. However, the current Employee Satisfaction level is not encouraging. Therefore, it is all the more important for the EPC companies to concentrate in improving the Employee Satisfaction Level.

6. CONCLUSION

The study concludes that the Employees working in EPC companies have very high level of dissatisfaction in areas such as stress level, working hours, equality & respect, recognition and promotional opportunities. The Study also concludes that the Employee Satisfaction level can be improved by providing proper Training to Employees, good salary and increment on yearly basis, 5 days a week,

reduced working hours, periodical performance appraisal, improvement in feedback system. The EPC companies in Oil & Gas Industry of UAE need to look into these aspects. It can be deduced from the above that if the EPC Companies device means and methods to increase the Job Satisfaction of their Employees, it shall have a direct bearing on the Employee Satisfaction resulting in higher retention level and leading to EPC Companies achieve their goal of higher productivity, increase in profitability etc.

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Time study in Wire Mesh Industry to Enhance Agility

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Abstract: This case study is based on one of the wire making industries in south Gujarat GIDC. The main purpose of this paper is to study and understand importance and core consequences of lean manufacturing system and agile manufacturing system in the industries. Today's globalization of low cost market and dynamic demand of customers in this scenario it is important to adopt lean manufacturing and agile manufacturing system and sustain the today competition. In this case study we carried out huge literature survey on lean manufacturing system and agile manufacturing system and understand its importance and study how to implement in wire making industry by use of ideal time study data system. To implement agile manufacturing system and its quality tools it is important to implement first lean manufacturing system. Now based on observation and literature survey we study the whole system of our selected industry. And we show the wire mesh machines are representing low productivity compares to their capacity. So we carried out ideal time study on that machine and identify many problems but, when we study that data we see that one of those problems is cross wire shortage which is caused by wire straining machine so we also carried out ideal time study of that. By ideal time study data of wire mesh machine, we identify some core problems which are possibly responsible for their low productivity and which are as follow (cross wire shortage). Now, we also identify some problem from ideal time study data of ST machine and which are as follow (wire mesh). The lean and agile manufacturing has many benefits because they impact on whole system both technical models as well as on management model. The lean manufacturing system is eliminate the major wastes which are very important, and on other hand agile manufacturing system induce flexibility in industry. So, that industry easily handle huge work load during peak load hours without compromising the quality. This paper represents the time study analysis of the organization which will help the organization to increase the agility.

Keywords: Agility, lean manufacturing system, agile manufacturing system

1. INTRODUCTION TO AGILE MANUFACTURING

According to Oxford dictionary, lean means “strong” and “efficient”. The other meaning mentioned is “thin and fit”. At the beginning of twenty-first century lean manufacturing system was introduced. Lean manufacturing is all about eliminating the various wastes in systematic manner. Lean manufacturing professionals have so far identified as many as nine wastes that occur in organizations (Sullivan et al., 2002; Dahlgaard and Dahlgaard-park, 2006) namely Overproduction, Unnecessary inventory, Delay, Transportation, processing, Unnecessary Motion, defective parts, underutilization of people and Underutilization of facilities. Lean manufacturing professionals have so far identified as many as nine wastes that occur in organizations (Sullivan et al., 2002; Dahlgaard and Dahlgaard-park, 2006). Now, lean manufacturing paradigm enables an organization to achieve high degree of quality and productivity through waste elimination due to customer's dynamic demands. Hence, organizations are required to adopt flexible strategies. On realizing this requirement first of all “agile manufacturing system” introduced. “Agile manufacturing is paradigm that enables an organization to quickly react in accordance with the dynamic demands of the customer by making use of appropriate technologies and management models.” Agile

manufacturing system prefer the cell production method because it's very easy to evolve in the task of meeting customers dynamic demand within the short time duration without compromising the quality, productivity and profitability and all the employees becoming the team members of this manufacturing cells. The researchers have found out that numerous technologies and management models have to be adopted to implement agile manufacturing paradigm (Sharifi and Zhang, 2001). This process will also lead to the intellectual summation of flexible manufacturing system and lean manufacturing paradigm (Sarkis, 2001). The principles of agile manufacturing were formalized, several researchers have identified the criteria that would establish agile manufacturing environment. Most of these researchers enumerated management-oriented criteria for attaining agility in organizations. Agile manufacturing criteria have been grouped into four criteria under titles: management driver, “technology driver”, “manufacturing strategy driver” and “competitive driver”. These groups are arranged in the ascending order of the quantum of the resources required for their implementation.

2. LITERATURE REVIEW OF AGILE MANUFACTURING

A new agility development method for dealing with the interface and alignment issues among the agility drivers,

capabilities and providers using the QFD relationship matrix and fuzzy logic.(Yi-Hong Tseng, Ching-Torng Lin.2011). A conceptual model, based on joint research, which has been developed to identify where UK's best practice companies are in their quest to become agile manufacturing organizations. In support of this, a questionnaire has been developed and completed by best practitioners of manufacturing, to assess the model, and establish whether they are making progress to becoming agile manufacturing organizations (J.M. SHARP, Z. IRANI, S. DESAI. 1999). The role of inventory and capacity in accommodating such variation and identifies how TRIZ separation principles and TOC tools may be combined in the integrated development of responsive and efficient supply chains. A detailed apparel industry case study is used to illustrate the application of these concepts and tools (R.Stratton, R.D.H.Warburton.2003).

GECMAe's agile manufacturing experience is reported, including a list of recommendations for improving its competitiveness. In addition, a framework has been formulated to highlight some important areas and to offer solution alternatives not only to the current problems but also to the ones that may be encountered in the future (A.Gunasekaran, E. Tirtiroglu, V. Wolstencroft .2002). The management strategies and the methodologies to be used on

the pathway to fully implement lean manufacturing will be discussed, taking into account mound making companies classical constraints(P. Peças, E. Henriques, 2003). A conceptual generic model, which covers the quality-based functions and their interrelationships. Implementing the model will assure high quality in the eight quality creation processes of definition, design, development, production, delivery, sales and service, use and disposal/recycle of customized product (A.S.Nookabadiand J.E.Middle. 2004).

3. COMPANY PROFILE

Name: Systematic Steel Industries Limited.

Address: plots 1229 & 1230, Gujarat industrial development corporation, Sarigam, Gujarat.

Products: Armour wire, ACSR wire, Electro & hot-dip galvanized wire etc.

No. of Peoples work: 65

4. DATA COLLECTION AND ANALYSIS

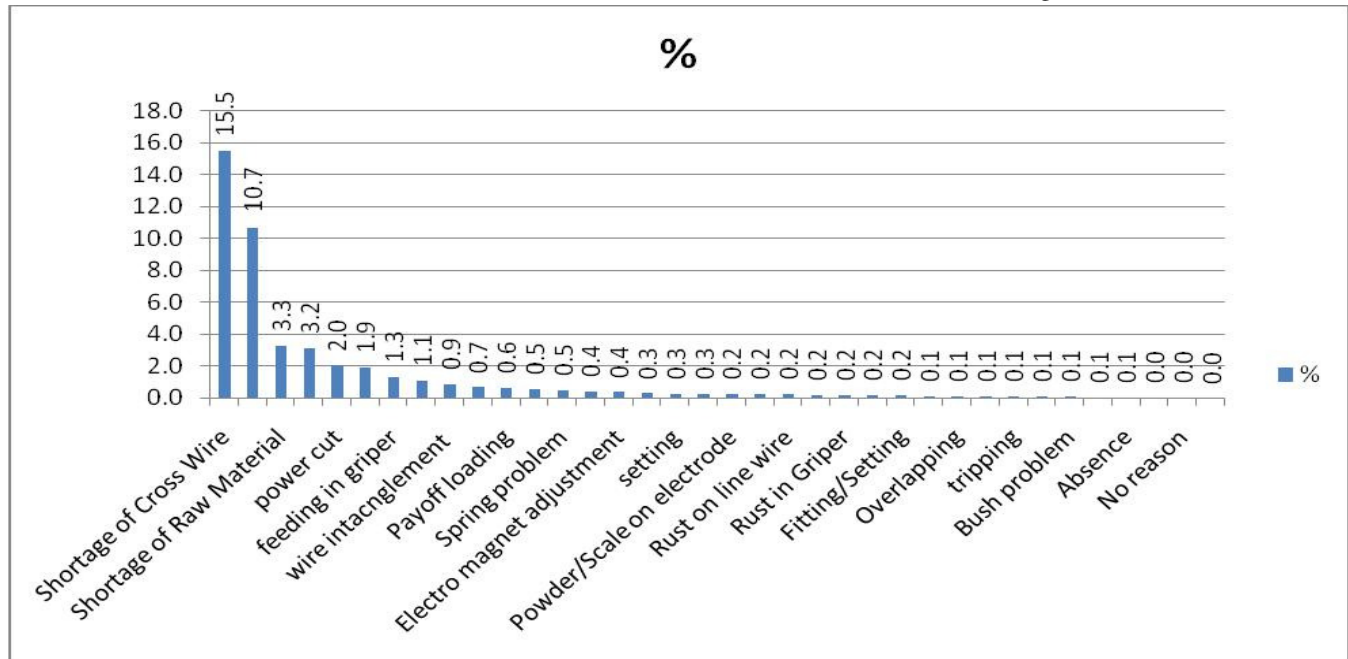
We studied the plant of the industry and we observed that the maximum wastage was carried out in weld mesh plant, so to identify the problem, we study the Ideal time of weld mesh machine and collected the data of weld mesh for 7 days for 7 hours.

Problem	sub problem	9/9/2016	9/10/2016	9/15/2016	9/16/2016	9/17/2016	9/22/2016	9/24/2016	Total
Wire Stand	wire intacklement	0:01:05		0:03:55		0:05:54	0:13:53		0:24:47
	PF loading	0:05:50	0:07:32				0:04:00	0:43:58	1:01:20
Rolling & manual welding	wire Traffic	0:07:31		0:09:30			0:15:36	0:02:28	0:35:05
	manual of cross wire & line wire		0:09:33	#####	0:03:38	0:15:00	0:30:00	0:28:03	2:00:49
Cross wire	Shortage	2:38:50	1:54:19	#####	1:45:15	0:19:00	0:39:49	0:07:14	7:42:27
	falling							0:02:07	0:02:07
	length short cutted						0:08:54		0:08:54
	alignment		0:03:56						0:03:56
	overlapping			0:01:09	0:00:42	0:01:40		0:01:14	0:04:45
	Rust Material		0:00:50						0:00:50
Lunch Time		0:51:00	12:54:00 AM	0:43:00	0:51:00	0:53:00	1:03:00		5:15:00
Tea break		0:05:44		0:10:00					0:15:44
Sheet	alignment after welding	0:01:30							0:01:30
Operator	Absence	0:00:01						0:02:00	0:02:01
	over counting of stock	0:02:00	0:01:08	0:02:36	0:00:20		0:00:10		0:06:14
	No reason			0:01:00					0:01:00
Electrode	Problem in electrode	0:03:00		0:15:57	0:00:35				0:19:32
	Electro magnet adjustn	0:10:00					0:01:00		0:11:00
	powder on electrode	0:07:00							0:07:00
	Fitting			0:02:12			0:01:16		0:03:28
Brake	Maintance		0:00:20						0:00:20
Griper	Rust in Griper						0:06:13		0:06:13
	Break Down		0:06:28						0:06:28
	Spring problem						0:13:23		0:13:23
Cam Shaft	Setting		0:03:34				0:01:22		0:04:56
Weld Head	Bush problem		0:02:36						0:02:36
	changing						0:13:23		0:13:23
Raw Material	Shortage			0:53:00		0:43:00			1:36:00
	Rust of line wire					0:07:05			0:07:05
Line wire	feeding in griper			0:14:54	0:04:56		0:17:59	0:04:58	0:42:47
Cooling system	No proper supply of coolant in system			0:17:41			0:38:17		0:55:58
Earthing Wire	setting					0:01:00		0:07:32	0:08:32
	power cut					1:00:00			1:00:00
Bearing	offset						0:08:00		0:08:00
	feitting						0:05:00		0:05:00
Electrical	treep						0:04:00		0:04:00
TOTAL		04:13:31	03:24:16	03:47:29	02:46:26	03:25:39	04:45:15	01:39:34	00:02:10

5. CONCLUSION

From the collected data we found that the Shortage of cross wire and Shortage of Raw material are the major problem

for the brake down of weld mesh machine. By data analysis we came to now that the major problem or brake down phase by us is due to cross wire shortage from data collection for weld mesh shortage of cross wire is 15.51%,



6. RECOMMANDATION

- Company has to make the proper policy for the quality management.
- Company makes to proper team for the agile manufacturing system implementation.
- Fixed the lunch time (if possible)
- Prepare the work schedule and proper production planning for the shortage of raw materials
- Prepare a check sheet for the regular maintenance work

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Using Template to Reduce Time to Draw Isometric Drawing

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Abstract: The objective of this research was to find out whether using a specially developed isometric template helps students to reduce time and efforts while drawing isometric drawings. The standard method of comparison of performance of two groups has been used to achieve the objective. An Isometric template specially designed was given to a group of 15 students. The time measurement has been done on group using stopwatch performed by volunteers. It has been found that the group using the template shown average reduction in time of about 3.39 min. This time reduction is very much of importance at the time of examination. There has been no such kind of effort has been carried out for the objective stated above. The application of this tool may be useful for the students of technical education such as ITI, Diploma, and Engineering etc. The template can be improved by adding various other features like circles of various diameters, French curve, a roller etc. such that it can be useful for other drawing concepts.

Keywords: Isometric drawing; Engineering graphics; Isometric template; Technical drawing.

1. INTRODUCTION

The concept of an Isometric had existed in a rough empirical form for centuries. From the middle of the 19th century isometrics became an invaluable tool for engineers, and soon thereafter axonometric and isometric were incorporated in the curriculum of architectural training courses. According to Jan Krikke, "axonometric originated in China. Its function in Chinese art was similar to linear perspective in European art. Axonometry, and the pictorial grammar that goes with it, has taken on a new significance with the advent of visual computing" An isometric drawing is one of the most used drawings in engineering education. It also has a reputation of one of the most difficult to understand and draw. However the basic principal behind its inclusion in engineering curriculum worldwide is to develop imagination power of the students. It basically contains of three axonometric drawings and they are matched or imagined in such a way that they create a parallel projection technique. In Isometric drawings, the image plane is associated with the three principal axes which make equal angles. The three principal axes as shown in the Figure 1 are inclined at 120° and also parallel to the cube edges in the Isometric view. These three principal axes are known as isometric axes. There are two receding axes which are inclined at 30° to the horizontal line while the vertical axis is at 90° to the horizontal line. There are three planes called as isometric planes or isoplanes which contains the three visible faces of the cube. The lines from object which are parallel to the isometric axes are referred to as isometric lines whereas non parallel lines are known as non-isometric lines.

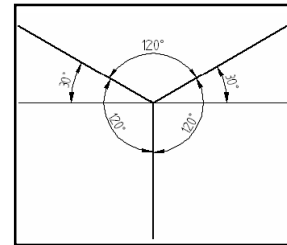


Fig. 1. Isometric axes in image plane

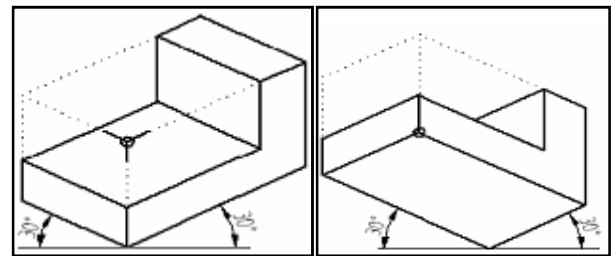
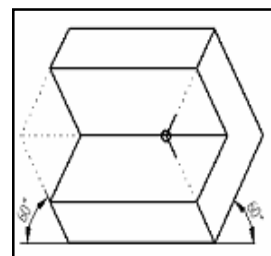


Fig. 2 a) Regular b) Reverse isometric



c) long-axis isometric

1.1 Importance of Isometric Drawing

Interpretation of the shape of an object from a multiview orthographic drawing requires a thorough knowledge of the principles of orthographic projections. A pictorial projection in general and an isometric projection in particular, helps the students and also the shop floor workers (from whom the knowledge of orthographic projection is not expected) to visualize clearly and fully the shape of the object. Pictorial drawings are mainly used to show complicated structures such as aircraft, rocket cell etc. Pictorial drawings in the form of exploded views are used in maintenance catalogues and manuals.

1.2 Types of Isometric Drawings

Different isometric views of an object can be obtained by positioning Isometric axes.

Three basic views are

1. Regular isometric,
 2. Reverse isometric
- And

3. Long-axis isometric as Shown in Figure 2.

In regular isometric, the viewer is looking from top down position so that the top of the object is seen. Whereas reverse isometric is exactly opposite to this view, Long axis is some kind of different view which is not generally used to describe the object.

1.3 Isometric Template

The Isometric template used in this research was apparently influenced by the Iso-sketch tool innovated by The Drawing Tool Company [4] [5] as shown in Figure 3a) & 3b). The template design is shown in Figure 2. It is consisting of various portions which are generally required to draw an isometric drawing. The template used in this particular research is as shown in Figure 3c) is having 30° lines from horizontal, The template was also designed by considering ergonomics of age group who are using it. The plastic material was used for it due to its various advantages over other materials. Figure 5 represents the actual prototype of the isometric template used by the group of students in this research.



Fig 3 a) Iso-sketch Tool

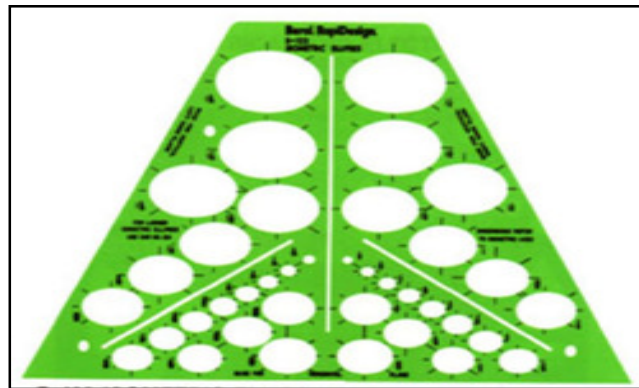


Fig. 3 b) Isometric Template

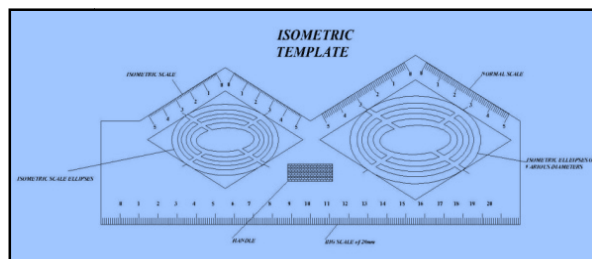


Fig 3 c) Newly designed Isometric Template

2. RESEARCH METHODOLOGY

A group of 30 students [15 test candidates- 15 Volunteers] from First year of engineering class have contributed for the study first an isometric problem as shown in Figure 4 was discussed and taught to the all students appearing for the

test. The test candidates are then said to solve the problem again on a blank sheet. The 15 student volunteers out of 30 were asked to record the time required for solving the problem with simple drawing tools, and with using isometric template. They were first instructed how to use this tool/ template. And also the time required for the

drawing was calculated by volunteers. The data found is tabulated in Table1. A comparison was made and the results were plotted graphically as shown in Figure 6.

TABLE 1: comparison of time in min required for regular method and by using isometric template

Student Roll No.	Regular Method	Using Isometric template	Decrease in time reqd in min
1	12	8.21	3.79
2	11	7.53	3.47
3	12.21	8.3	3.91
4	13	9	4
5	13.11	9.14	3.97
6	9.55	6.56	2.99
7	15	9.45	5.55
8	14.48	9.52	4.96
9	11	8.14	2.86
10	11.09	7.3	3.79
11	11.37	8	3.37
12	10.1	9.36	0.74
13	10.53	9.4	1.13
14	16.46	13.11	3.35
15	17.1	14	3.1

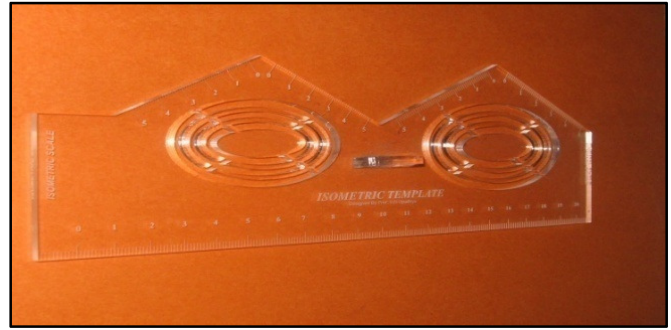


Fig 5 Prototype of Isometric Template

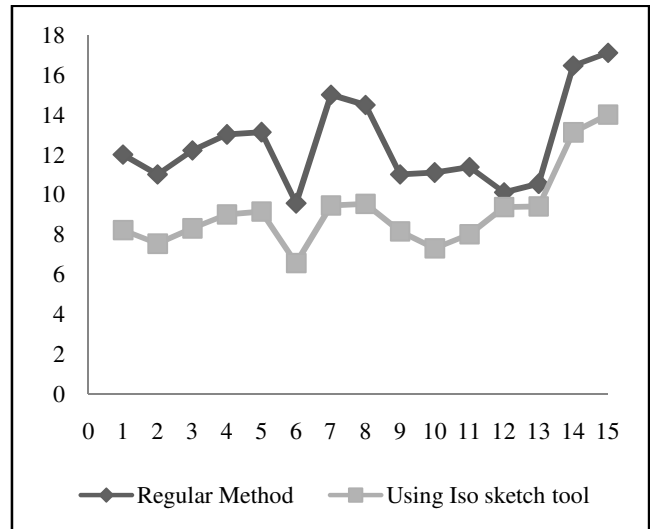


Fig. 6. graphical representations of data from Table.no 1

2.1 The Data Found Out Was As Follows.

The average time reduction while drawing an isometric drawing using an Isometric tool has been show in Table 2. This clearly shows that there is significant reduction in time of about 3.39 min if student uses an Isometric template. Figure 7 represents the graphical plotting of these results.

TABLE 2 Average time reduction to draw Isomteric drawing using Isometric template

	Regular Method	Using Isometric template
Students appeared	15	15
Average time required to solve question in min.	12.53333 Min.	9.134667 Min.
Avg. time reduced to draw isometric using iso template tool	3.398667 Minutes	

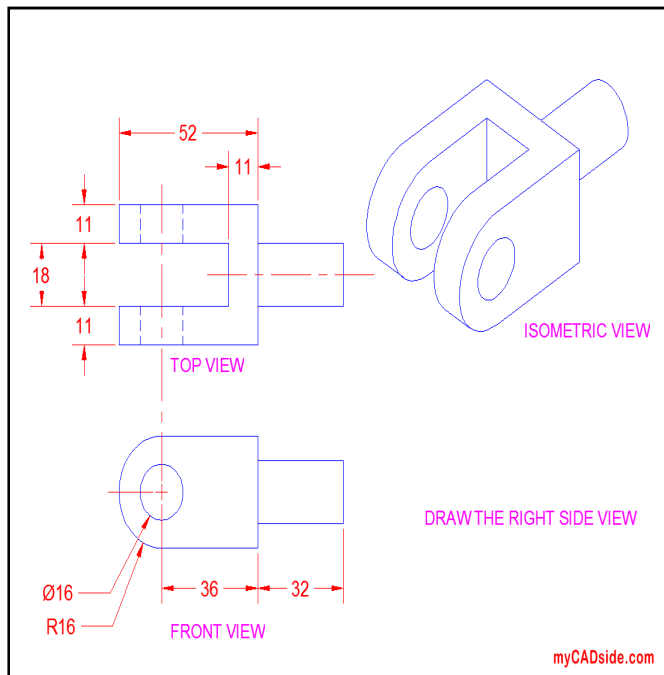


Fig. 4. Isometric Problem Discussed

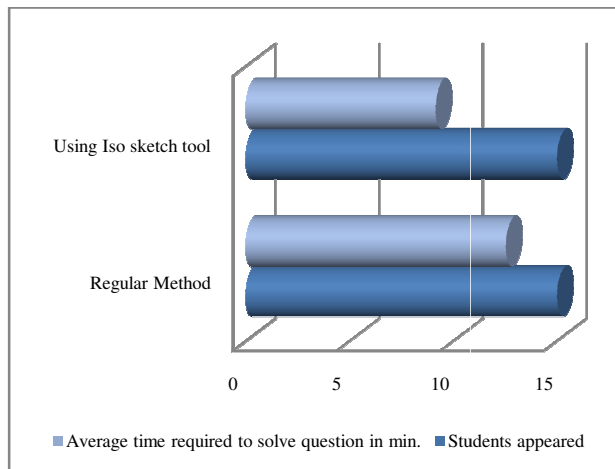


Fig. 7. Graphical representations of data from Table 2

3. CONCLUSION

Results of the tests carried out shown an encouraging

decrease in the time required to solve an isometric problem i.e. about 3.39 min. Hence it is found that using isometric template to solve a problem might help the students in exam so that their performance gets increased.

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Development and Validation of Safety Climate Questionnaire for Manufacturing Industry in India

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Abstract: The objective of this paper is to develop and validate a safety climate questionnaire or safety related perception of workers to study the safety and health conditions in small and medium scale industries in Punjab. Safety is big concern for organizations because it leads to many direct and indirect costs. Safety climate is the employee's perceptions of policies, procedures, and practices regarding safety in an organization. The purpose of this study is to develop and explore the content and face validity and internal consistency of the safety climate questionnaire for manufacturing sector in India. The questionnaire is developed through literature review and discussions with experts. Panel of seven experts who consist of safety officers, professionals have vast experience of manufacturing sector in India. Content validity was measured by content validity index (CVI) and a modified kappa index. A pilot study was conducted to test the internal consistency of the questionnaire by calculating Cronbach's alpha. Thirty out of forty-five items showed excellent content validity, six items showed good content validity, eight items showed fair content validity, and one item showed poor content validity. The average content validity of the questionnaire was .80 and ranged from .79 to .92 for the six subscales. The face validity was good with no major remarks were given. We conclude that questionnaire showed good content validity and this questionnaire seems to be an acceptable tool to evaluate safety climate.

Keywords: Safety climate, Content validity index, Modified kappa index, Cronbach's alpha

1. INTRODUCTION

The Bhopal gas tragedy that occurred in India was an eye opener for industry in India. Investigation and studies of this incident revealed the lack of seriousness of human life by company management, ignorance and complacency of workers and totally irresponsible attitude from regulatory agencies (Gupta, 2002). Learning lessons from this incident and realizing the large compensatory expenses, production losses, and loss of confidence of workers, company managements in India have shown interest to invest for safety infrastructure in all types of industries, especially, major accident hazard industries (ILO, 1996).

Even after two decades since the Bhopal disaster, the fatal accident rate in Indian manufacturing sector stay close to 20 fatalities per hundred thousand employees against 1-6 in advanced countries (DGFALSI, 2006). According to the data of DGFALSI there are around 1383 fatal and 28441 non fatal injuries occurred in India in 2012. In India the management of occupational safety and health of workers at organizational level is governed by The Factories Act, 1948 (Central Act 63 of 1948) and rules formed there under by the state governments. Recently there has been a movement away from safety measures purely based on retrospective data or "lagging indicators" such as lost time accident rates and incidents towards so called "leading indicators" such as safety audits or measurement of safety climate (Flin et al., 2000; Mohamed, 2002).

1.1 Safety climate

Safety climate can defined as employees shared perceptions of safety policies, procedures, practices as well as overall importance and the true priority of safety at work (Griffin and Neal, 2000; Zohar, 1980). It is multidimensional factor. Safety climate was considered to be a part of organizational climate and reflected the employee's attitude and perceptions at a particular time and at a particular place (Schneider and Gunnarson, 1991; Cox and Flin, 1998; HSE, 1999). Safety climate provides a snapshot of an organizations "state of safety" at a discrete point in time (Cheyne et al., 1998; Huang et al., 2007).

Zohar (1980) developed the first measure of safety climate, using a 40 item questionnaire covering the metal fabrication, textiles and food processing industries. After factor analysis his model included eight factors with workers perceptions of the importance of safety training, management attitude towards safety, effects of safe conducts on promotion, level of risk, work pace, status of safety officer, effects of safe conducts on social status and status of safety committee. Brown and Holmes tried to replicate this structure in America and found that it was not supported. They arrived at new set of three factors. Hale (2000) noted that few safety climate have been reused between studies and that whenever this has occurred, factor structures and results have not usually been replicated.

In recent decades, it has been well documented that safety climate is related to safety behavior and unintentional injuries in workplaces in western countries. A recent meta-analytic review revealed that safety climate offer robust predictions of the occurrence of occupational injuries and better self reported safety behavior across industries (Clarke, 2000a). Moreover, it was found that a positive safety climate can encourage safe performance either through rewards or through principles of social exchange (Zohar, 2000; Clarke, 2006). A number of studies showed that safety climate was associated with safety behavior and lower workplace accident rates (Griffin and Neal, 2000; Zohar, 2000; Sin et al., 2004; Smith et al., 2006; Clarke, 2006; Zohar et al., 2014). As to the safety climate in manufacturing enterprises, there were a lot of investigation reports in many countries. Zohar (2000) found that safety climate predicted micro accidents records at a manufacturing plant.

Many studies have investigated the construct of safety climate in organizations. However, they have not reached to a common agreement on safety climate dimensions. The review of previous studies showed that management commitment to safety is a common dimension for safety climate. Seo et al. indicated that safety climate dimensions can be categorized into five themes: management commitment to safety, supervisor safety support, employee participation, and competence level of employee about safety. A review of 18 safety climate surveys by Flin et al. revealed that safety system, management, risk, work procedure, and competence were the most frequent dimensions. Flin et al. also identified work pressure as another frequently used dimension. Safety communication, safety training, work environment, safety information were found as other dimensions of safety climate.

There are several methods to assess the validity of a questionnaire. The content validity of a questionnaire can be examined in development and judgment stages. The development stage is usually carried out through performing a literature review or conducting interviews with focus groups. The quantitative analysis of the content validity is determined by application of statistical methods. The content validity index (CVI) is one of the methods to find out the validity of a questionnaire.

To the authors' knowledge, this study is the first one to develop and to validate a safety climate questionnaire for manufacturing industry in India. Because of unique nature of safety climate in countries, industries, companies, and even different sector of organization, we found a need to develop a new questionnaire to examine safety climate in Indian manufacturing industry. In this study, we developed a new safety climate questionnaire and also examine its validity.

2. METHOD

2.1 Development of questionnaire

A literature review conducted and a total of 345 safety climate items generated from the available questionnaire in the published articles and the documents. The number of items reduced to 46 after discussing with experts related to manufacturing industry. We identified five dimensions of the safety climate and those dimensions are management commitment, safety training, safety communication, safety knowledge and compliance, work pressure.

2.2 Experts' agreement on item relevance

The questionnaire was tested for content validity (Lynn, 1986; Pilot et al., 2000). Each of the experts was asked to rate each questionnaire item on its relevance using a 4-point Likert-type format, ranging from "highly relevant" (score 4), "quite relevant" (score 3), "somewhat relevant" (score 2), to "not relevant" (score 1). In addition, experts were asked to indicate whether an item's wording should be revised. If the expert recommended revision, he/she was encouraged to revise the item.

An item content validity index (I-CVI) was calculated for each item. For the total questionnaire and each scale, a scale content validity index (S-CVI) was calculated. There are two methods for calculating content validity of whole scale or questionnaire. The first method is the universal agreement method as proportion of items that achieved a rating of 3 or 4 by all experts. The second method was to calculate the average of all the I-CVIs of the individual items (S-CVI Ave). Content validity indexes were rated as good when I-CVI, S-CVI Ave and S-CVI UA were at least 0.78, 0.90, and 0.80, respectively (Pilot et al., 2000). The I-CVI is the proportion of experts who rate its content as valid (a relevance rating of 3 or 4) (Lynn, 1986; Pilot et al., 2000). To calculate a S-CVI, different methods were tested (Pilot et al. 2000). The first method was to require 'universal agreement' among experts, defining the S-CVI as the proportion of items on an instrument that achieved a rating of 3 or 4 by all the experts (S-CVIUA). The second method was to calculate the average of all the I-CVIs of the individual items (S-CVI Ave). Content validity indexes were rated as good when I-CVI, S-CVI Ave and S-CVIUA were at least 0.78, 0.90, and 0.80, respectively (Pilot et al., 2000).

To counter the limitations of the CVI, an I-CVI was computed correcting for chance agreement by calculating modified kappa statistic (k^*), which is the index of arrangement among experts that the item is relevant (Pilot et al., 2007). To compute the modified kappa, first we have to calculate probability of chance agreement: $P_c = [N! / (N-A)!] * 0.5^N$ where N is the number of experts and A is the number of experts give rating 3 or 4. k^* was calculated with formula $k^* = [I-CVI - P_c] / [1 - P_c]$ (Pilot et al.,

2007). Finally standard values described in Flies (1981) and Cicchetti and Sparrow (1981) were applied to evaluate whether the K value was fair, good, excellent.

2.3 Face validity

The face validity was tested by 5 experts who have the knowledge and experience about worker's safety in

manufacturing industry in India. They studied the questionnaire and were guided by questions such as: "Are these questions understandable and clear? If 'no' please indicate the item and feel free to propose a better formulation." Comments were then discussed by the researchers.

S. No	Management commitment	Total no. of Experts	Number of experts give rating 3 or 4	I-CVI	Pc	K*
1	My company responds quickly to safety concerns	7	7	1	0	1
2	My company provides safety information	7	7	1	0	1
3	My company investigates safety related problems	7	4	0.57	0.273	0.4
4	My company provide enough & good safety equipments	7	7	1	0	1
5	My company emphasizes safe working conditions	7	6	0.85	0.054	0.84
6	Safety inspections are carried out regularly	7	6	0.85	0.054	0.84
7	Management considers safety to be equally important as production	7	5	0.71	0.164	0.65
8	Safety is given high priority by the management	7	6	1	0.054	0.84
9	Management accepts advice about safety	7	7	1	0	1
10	Management is concerned about our well being.	7	7	1	0	1
11	Management have clear & useful safety policy	7	5	0.71	0.164	0.65
	Safety Training					
1	I have been offered enough training in PPE	7	7	1	0	1
2	Safety training given to me is adequate to enable me to assess hazards in work areas	7	7	1	0	1
3	Newly recruits are trained adequately to learn safety rules and procedures	7	6	0.85	0.054	0.84
4	Safety training programs help prevent accidents	7	4	0.57	0.273	0.4
5	I have been offered regular and useful safety training	7	5	0.71	0.164	0.65
6	Training about new procedures and equipments	7	7	1	0	1
7	Training plan decided jointly with workers	7	5	0.71	0.164	0.65
8	Safety issues are given high priority in training programs	7	6	0.85	0.054	0.84
	Safety communication					
1	There is open communications about safety issues in this work place	7	7	1	0	1
2	Management consults with employees regularly about work place health and safety issues	7	6	0.85	0.054	0.84
3	Communication with supervisors regarding safety matters is easy	7	6	0.85	0.054	0.84
4	There is sufficient opportunity to discuss and deal with safety issues in meetings	7	7	1	0	1

5	Do you generally avoid talking about safety issues with your supervisor	7	6	0.85	0.054	0.84
	Safety knowledge and compliance					
1	I know how to perform my job in a safe manner	7	7	1	0	1
2	I use all necessary safety equipments to do my job	7	7	1	0	1
3	I know how to use safety equipments and standard work procedures	7	4	0.57	0.273	0.4
4	I carry out my work in a safe manner	7	3	0.42	0.273	0.2
5	I know how to reduce the risk of accidents and incidents in the workplace	7	7	1	0	1
6	I know what are the hazards associated with my job and the necessary precautions to be taken while doing my job	7	7	1	0	1
7	Use a tool to adjust a dangerous part of a machine	7	6	0.85	0.054	0.84
	Work Pressure					
1	I believe there is sometimes pressure to put production before safety	7	7	1	0	1
2	Rules relating to personal safety sometimes make it difficult to keep with production target	7	7	1		1
3	My health has been negatively affected by my work	7	5	0.71	0.164	0.65
4	We're just running around all the time from one job to another, not completing them properly	4	4	0.57	0.273	0.4
5	I have unachievable deadlines	7	6	0.85	0.054	0.84
6	I have to work very intensively	7	6	0.85	0.054	0.84
7	I have to neglect some tasks because I have too much to do	7	7	1	0	1
8	I am unable to take sufficient breaks	7	5	0.71	0.164	0.65

The 'bold and underline values 'shows an item with content validity index below 0.78.

I-CVI (item content validity index) = number giving a rating of 3 or 4/number of experts.

Pc (probability of a chance occurrence) = $[N!/A!(N-A)!] \cdot 0.5^N$ where N = number of experts and A = number agreeing on good relevance.

K* = kappa designating agreement on relevance: $k^* = (I-CVI - pc)/(1 - pc)$.

Evaluation criteria for kappa: fair = k of 0.40–0.59; good = k of 0.60–0.74; and excellent = k > 0.74.

S-CVI Ave (average scale content validity index) = mean of I-CVI

3. RESULTS

3.1 Validation of questionnaire based on experts' agreement

Seven experts evaluated the questionnaire out of which all had more than five years of experience in manufacturing

industry. Thirty five out of forty five (78%) questionnaire items showed excellent content validity ($I-CVI \geq 0.78$ and $K^* > 0.74$), six items (13%) showed good content validity ($I-CVI < 0.78$ and $0.60 \leq K^* \leq 0.74$), four items (9%) was considered as fair ($I-CVI < 0.78$ and $0.40 \leq K^* \leq 0.59$), one item considered poor and invalid ($I-CVI < 0.78$ and $K^* \leq 0.4$). The scale content validity for the questionnaire was 1.26, indicating that the amount of items with unanimity among experts was low. The average scale content validity (S-CVI Ave) was 0.71 below the cut off 0.90.

S-CVI Ave. and S-CVI UA for the management commitment were 0.88 and 0.54, for safety training 0.83 and 0.37, for safety communication 0.91 and 0.4, for safety knowledge and compliance 0.83 and 0.57, and for work pressure 0.83 and 0.37.

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A Study of Power Sector - Safety Issues & Indian Scenario

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Abstract: Power sector plays a major role in the industrial & economic development of a country. In India it is increasing by more than 5.5 % annually, thermal power plants accounting for more than 85 % of the utility power generated . Concern for depleting fossil fuel reserves, pollution & safety related issues has compelled the power ministry to reframe its power generation policy including development of power plants based on renewable energy sources (RES) . In this paper, different sources of energy used for power generation, related safety issues, the current Indian scenario & government policy pertaining thereto have been discussed.

Keywords: Thermal, Nuclear, Hydel & other RES based power plants

1. POWER SECTOR & RELATED SAFETY ISSUES

Electricity is essential for industrial development, economic growth and improving living condition of people . The power sector thus plays a very important role in society . Power generation involves conversion of an available form of energy using an appropriate method . Compared to thermal / nuclear power plants, RES based power plants have low operating & maintenance cost, do not emit any pollutants or pose any serious health hazard or cause depletion of our fossil fuel reserves . The various sub types of RES are discussed below :-

Solar based power plant - Solar power plants are considered as the safest, cleanest, cheapest & most eco friendly method for generating power. These are particularly suitable for areas having predominantly hot, dry & sunny weather. Depending upon the method of conversion of solar energy into electric, these are of 2 types. a) Solar Thermal power plants – The sunlight is collected & concentrated using parabolic mirrors / lenses to heat water & produce the high temperature steam required for power generation, even long after sun set. This is less popular because of requirement of considerable water, water treatment, scaling & corrosion problems, comparatively higher installation, operating & maintenance cost. b) Photo-Voltaic power plants –Here, numerous solar panels (composed of interconnected photo-voltaic cells) are set up on a strip of infertile / unproductive land (called solar farm). When exposed to sun light, these solar panels generate electricity. Smaller solar panels can be installed on building rooftops / light posts for household & street light electrification. The power generated during daytime has to be stored in batteries for consumption after sunset. Solar panels & batteries are not prohibitively expensive, installation, operating & maintenance cost is low. With the

advent of thin polycrystalline solar panels at much cheaper rates, PV solar plants are becoming increasingly popular.

Wind based Power Plant - This is suitable for places regularly experiencing high wind velocities. A wind farm consists of several wind turbines being placed in a zig-zag array ; the spacing being 5 – 9 times rotor diameter across the prominent wind direction and 3 – 5 times rotor diameter along the prominent wind direction. Higher the height of the rotor hub above ground (usually 100 – 120 m), higher the wind velocity & greater the power generating capacity. The initial equipment & setup cost is substantially high but operating & maintenance cost is low & land requirement is < 1 acre / MW, The in – between space can be used for cultivation, cattle grazing or setting up solar panels as in Solar – Wind hybrid power plant.

Biomass based power plant - Biomass is organic matter obtained from living / dead organisms eg. cow dung, rice husks, crop stalks, agro residue etc., which is abundantly produced in rural areas. If burnt or left to decay, it would emit green house gasses & cause pollution. Alternatively it can be beneficially utilized as a fuel source (as biomass or biogas) not only for domestic cooking but also in small thermal power plants, to produce steam for power generation for village electrification & agro / allied industries (sugar, brewery, rice mill, paper, textile, fertilizer, etc.).

Geothermal based Power Plant - In the vicinity of volcanic activities / hot springs, underground water is usually available at high temperature & pressure. Using deep drilling & extraction technology, this water is pumped to the surface in steam form & used to rotate a turbine for generating electricity. The underground water temperature should be > 180 °C in flash steam type, > 150 °C in dry steam type or even > 60 °C in binary cycle type power

plant. In the first 2 types, a mixture of gasses like CO₂, CH₄, NH₃, H₂S are released as air pollutants but in quantities much less compared to thermal power plants. Exploration & drilling cost is high, the thermal efficiency is low (only 7 - 10 %) but operational costs are quite low.

Tidal water based Power Plant - In coastal areas, the difference in water level heights during high tide & low tide creates tidal waves which periodically lash the sea shore with considerable energy. This energy is used to rotate a turbine & generate electricity. For the project to be feasible, the average height of the tidal waves should be significantly large, the project site should not adversely interfere with marine life / fishing / naval activities. They are susceptible to damage by tsunami & hurricane & power generation fluctuates with the tide but operation & maintenance costs are low.

Hydro-electric (Hydel) Power Plants - A dam is built across a fast flowing perennial river to form a reservoir on the upstream side. Controlled release of water from the reservoir via a penstock is used to rotate a turbine (mostly Francis type) & generate electricity. Hydroelectric power plants also *help in irrigation, flood control* & do not cause pollution but are not 100 % eco – friendly. During construction, a huge land area on the upstream side gets inundated & the vegetation therein decays, releasing a huge amount of green house gasses like CO₂ & CH₄. Also people residing along those parts (mostly tribal villagers) have to be relocated & rehabilitated. Water flow on the downstream side is greatly reduced, adversely affecting the livelihood of farmers / fishermen of those areas & often leading to water disputes between neighbouring states / countries. Hydroelectric power plants can cause disastrous floods on the downstream side, resulting in huge damage to government property, immense hardship & unquantifiable personal loss to families residing in the inundation zone. This may be due to emergency water release or dam failure caused by natural calamities like earthquake, flash flood, land slide etc. or man – made causes like terror attacks, improper dam construction, inadequate repair of old dams, malfunction of sluice gate operating system, human error in timing & rate of release of excess water Jain R.K, 2011; Sharma, 2013.. During dam design, due consideration should be given to foundation geology, seismic activities, susceptibility to landslides, average & maximum rainfall, permeability of dam material, provision for drainage of seepage water & adequate number of spillways. Proper rehabilitation schemes should be offered to the displaced tribals from upstream side in return for their co-operation. Construction / operational cost, water & power sharing during draught as well as excessive rainfall between upstream & downstream communities should be equitably finalized at project design stage to avoid subsequent disputes. Timing, duration & rate of release of excess water should be carefully calculated so as not to cause / aggravate

flood situation. Warning system should be installed & activated prior to release of water to prevent drowning of fishermen / bathers on downstream side. There should be a well designed & rehearsed emergency action plan (EAP) including inundation map for flood due to emergency water release / dam failure. People should not be allowed to swim, boat or fish in the reservoir within 500m of the inlet to the penstock. River dredging & dam repair should be undertaken periodically.

Nuclear Power Plants - When a minute quantity of fissile radioactive material (U²³⁵, U²³³, Pu²³⁹) is bombarded with fast moving neutron, its atom disintegrates into 2 lighter radioactive atoms (called fission fragments), releasing a huge amount of energy & ionization radiation. 2-3 fast moving neutrons are also emitted, causing further nuclear fission to occur in a chain reaction. In a nuclear power plant reactor, this nuclear fission is controlled using regulators (lead / graphite rods) to absorb neutrons & moderators (eg. light water, heavy water D₂O), to reduce the speed of fast neutrons - the heat released is used to produce superheated steam for power generation. Thermal efficiency > 40 % is attained due to higher steam temperature (> 600 °C). Fertile mineral Th²³² is available in comparatively greater quantity, which can absorb a neutron & convert to fissile U²³³. Natural uranium ore is scantily available, containing only about 0.7 % of fissile U²³⁵, remaining 99.3 % is fertile U²³⁸ which can absorb a neutron & convert to fissile Pu²³⁹. Very few countries have nuclear grade uranium deposits & constitute the NSG (Nuclear Suppliers Group). The mined uranium ore is concentrated by solvent extraction & ion exchange process, to obtain crude 70 – 90 % uranium concentrate in yellow cake form. This is calcinated to UO₃, hydrogenated to UO₂, passed through hydrogen fluoride & processed to obtain UF₆ gas. This is fed into the centrifuge in an enrichment plant where the heavier U²³⁸ migrates to the outer periphery & mixture containing 2 – 3 % of the lighter U²³⁵ is collected from the central core region. This enriched UF₆ gas is converted to uranium metal / UO₂ / uranium carbide salt, mixed with Th²³², converted into small cylindrical pellets, placed in stainless steel / Zirconium tubes & sealed. A reactor requires 100 – 300 fuel elements, each comprising of a cluster of 50 – 300 of these sealed tubes called fuel rods. A large amount of ionization radiation is emitted during the fission reaction, storage & handling of radioactive fuel material, recycling spent fuel material & disposal of nuclear wastes. These harmful radiations pose a major occupational health & environmental hazard. The International Commission on Radiological Protection (ICRP) recommends a max. occupational radiation exposure dose of 50 mSv / yr or a max. of 100 mSv in a consecutive five-year period. The radiation exposure dose is measured using a personal dosimeter & can be minimized by reducing exposure time, increasing distance from radiation source or by using a shield made of some radiation absorbing material like lead

or concrete. All personnel must be provided with protective clothing & adequately trained. The reactor is set up in a full containment facility having concrete / lead walls to prevent leakage of any stray radiation into the environment. This facility is however susceptible to damage by reactor explosion, earthquake or terrorist attacks and can cause extensive environmental disaster. Storage & disposal of radioactive nuclear waste in large quantity is an environmental hazard. The present practice is to mix it with concrete, pour it in steel drums & bury the sealed drums in abandoned mines or dump them in underwater ridges, more than 100 km from the shoreline. Fissile material can be used by terrorists to make nuclear bombs & so strict vigilance has to be maintained at fuel enrichment, fabrication & recycling facilities to prevent illegal smuggling Jain R.K, 2011; Rao 2012

Thermal Power Plants - These are large capital & labour intensive installations, spread over a vast land area, having high operational & maintenance costs. Based on Rankine cycle, super heated steam produced in a high pressure boiler (mostly water tube type eg. Babcock Wilcox) is allowed to expand adiabatically to rotate a turbine coupled to a generator for generating electricity. The boiler is fired by burning a fossil fuel (natural gas, diesel or coal) having high calorific value. Natural gas & crude oil are simultaneously discharged from on shore or off shore oil wells. Crude oil undergoes fractional distillation in an oil refinery to yield diesel, while natural gas is liquefied under high pressure for ease in transport. Coal has to be extracted from surface or underground mines & beneficiated in a coal washery at the pit head to reduce ash content & transport cost. Mining & processing a highly inflammable fossil fuel is very hazardous^[1]. Transporting it in bulk quantity over considerable distance to the power plant & storing it there is equally hazardous. Feeding coal into the furnace, removing & disposing huge quantity of ash there from requires special equipment & adequate precautionary measures. Boiler operation & maintenance requires specialized personnel & special precautions. Boiler feed water must enter via a water treatment plant to minimize scaling & corrosion problems. Boiler walls / tubes must be periodically cleaned, inspected & repaired. Thermal power plants emit a huge amount of green house gases (mainly CO₂, SO₂, NO_x) as well as a huge amount of suspended particulate matter (SPM - mainly fly ash & unburned carbon particles) which is a serious health hazard for all residents within a 5 km radius & harmful for the environment. So coal beneficiation, installation of dust collector & more efficient boilers is essential.

Power transmission & distribution - The power generated in various power plants are transmitted via high voltage (132 KV) transmission lines over long distances to a central grid for load wise distribution to the numerous consumers

via an intricate network of distribution lines & substations where the voltage is sequentially reduced. Transmission lines generate strong & harmful electromagnetic fields. So these should not pass through residential areas & should be located high above the ground. The power lines may break by uprooted trees during cyclones. Hence there should be strategically located automatic circuit breakers to prevent electrocution & short circuit. Linesmen should be well trained & provided with harness. The supporting towers are susceptible to lightning strikes & should be well grounded. Power thefts increase power cost for consumer, often result in fire due to short circuit / death due to electric shock & hence needs to be curbed. The high capacity step up & step down transformers contain transformer oil having a high flash point > 140 °C but can catch fire, so fire prevention & protection measures should be adequate. Small transformers set up in different parts of the cities & towns should be placed high above ground & well fenced with danger signboards to prevent unauthorized entry./ accidents.

2. THE CURRENT INDIAN SCENARIO

Power generated in different states are interconnected to form 5 regional grids – Eastern, North Eastern, Northern, Western & Southern. These grids have been synchronously interconnected in phases, in the period 1991 - 2013, to form a National grid, which is monitored & coordinated by Central Electricity Authority (CEA). Power transmission / distribution losses & power theft constitutes more than 20 % of power generated & is a cause for concern. As on 31/12/1947, India had coal based thermal power plant of 756 MW capacity, diesel based thermal power plant of 98 MW & hydroelectric power plant of 508 MW - a total installed capacity of 1362 MW only. As on 30/6/2017 the captive power generating capacity is 50289 MW & the utility power generating capacity (thermal, nuclear & large hydro) is 329231 MW, the type-wise distribution being given in Tab.1.

Coal based thermal power plants account for almost 60 % of the installed capacity for utility power, more than 85 % of utility power generation & roughly 72 % of the domestic coal consumption. Natural gas & crude oil are rarely used, mostly in captive power plants. Of the captive power plants installed, 28.4 % are diesel based & 12 % are gas based. Large plants are mostly operated by government undertakings like National Thermal Power Corporation (NTPC), North East Electric Power Corporation (NEEPCO) & Damodar Valley Corporation (DVC). The major thermal power plants are - Vindhyachal thermal power plant (6 x 210 MW, 6 x 500 MW) in Singrauli, Madhya Pradesh, Mundra thermal power plant (4 x 330 MW, 5 x 660 MW) & Mundra ultra mega (5 x 800 MW) power plant in Kutch, Gujarat, Talcher super thermal power plant (6 x 500 MW) in Odisha & Sipat super thermal power plant (3 x 500 MW, 3 x 660 MW) in Bilaspur, Chattisgarh.

TABLE 1: India's utility power generating capacity & Generation

Power Plant type based on Fuel used	As % of total Installed Capacity as on 30/6/2017	Generation in 2016-17 (Target for 2017-18) (1 BU = 1000 GWh)
Coal based –	59.1 %	944.9 BU
Gas based–	7.6 %	49.1 BU
Oil based–	0.3 %	0.3 BU
Total Thermal Power Plant	67.0 %	994.3 BU (1042)
Nuclear Power Plants	2.1 %	37.9 BU (41)
Large Hydro-electric Power Plant	13.6 %	122.3 BU (141.4)
Wind based –	9.8 %	46.0 BU
Solar based power plant –	3.7 %	12.1 BU
Biogas based –	2.5 %	Na
Small hydro based –	1.3 %	Na
Urban / Industrial waste based -	0.3 %	Na
Total Renewable energy source based power plant	17.6 %	58.1 BU

Hydel plants have an installed capacity of almost 50 GW, 92 % of which are large & operated by government undertakings like National Hydroelectric Power Corporation (NHPC), NEEPCO, DVC, Sutlej Jal Vidyut Nigam Ltd. (SJVNL), Tehri Hydro Development Corporation (THDC), Bhakra Beas Management Board (BBMB) & NTPC – Hydro. The major hydel plants are - 2400 MW Tehri dam on Bhagirathi river in Uttarakhand, 1960 MW Koyna dam on Koyna river in Satara, Maharashtra, 1670 MW Srisailem dam on Krishna river in Andhra Pradesh, 1500 MW Nathpa Jhakri dam on Sutlej river in Himachal Pradesh, 1450 MW Sardar Sarovar dam on Narmada river in Navagam, Gujarat, 1325 MW Bhakra Nangal dam on Sutlej river in Bilaspur, Himachal Pradesh.

Nuclear power plants in India are exclusively owned by the Central Govt., under administrative control of Dept. of Atomic Energy & operated by Nuclear Power Corporation Ltd. (NPCL). Uranium is imported from Russia, Mongolia, Kazakhstan, Namibia & Argentina. India has 22 units, mostly of PHWR (pressurized heavy water reactor) type, of 6.78 GW installed capacity at Rawatbhata in Rajasthan, Narora in Uttar Pradesh, Kakrapar in Gujarat, Kaiga in Karnataka, Tarapur & Jaitapur in Maharashtra, Kalpakkam & Kudankulam in Tamil Nadu.

Small hydro electric power plants & other RES (wind, solar, biomass, tidal, geothermal) based power plants are mostly privately owned small units under the control of Ministry of New & Renewable Energy (MNRE). National Institute of Wind Energy (NIWE) has helped in promoting wind based power plants in the last couple of years. Several wind farms have been set up in Rajasthan, Karnataka, Madhya Pradesh as well as along the coastal region of Tamil Nadu, Maharashtra, Gujarat, Andhra Pradesh & Kerala ; the total installed capacity is about 32 GW. Due to

the Southwest monsoon, 70 % of the generation occurs during June – November. The major wind power plants are - the 1500 MW Muppandal wind farm at Kanyakumari, Tamil Nadu ; 1064 MW Suzlon wind farm at Jaisalmer, Rajasthan ; and 528 MW Parakh wind farm at Dhule, Maharashtra. Solar power plants are becoming increasingly popular in numerous areas of Rajasthan, Andhra Pradesh, Tamil Nadu, Telengana, Gujarat, Karnataka & Maharashtra. The major PV solar plants are – 648 MW Kamuthi plant in Madurai, Tamil Nadu, 221 MW Charanka plant in Patan, Gujarat, 151 MW Welspun plant in Neemuch, Madhya Pradesh, 148 MW ReNew plant in Nizamabad, Telengana & 125 MW Sakri plant in Dhule, Maharashtra. The major solar thermal power plants are - 100 MW Dhursar plant, 50 MW Godawari plant (both in Jaisalmer, Rajasthan), 50 MW Megha plant in Anantpur. In the NTPC – Dadri thermal power plant at Ghaziabad, Uttar Pradesh, a solar heat exchanger has been installed in parallel with the high pressure coal fired boiler no. 6. Government is actively promoting biomass based power plants for village electrification. The 20 MW biomass power plant in Sirohi, Rajasthan is the largest of its kind.

3. GOVERNMENT POLICY & PLAN

Reducing power losses & theft is of top priority. India is concerned about depleting fossil fuel reserves, increasing air pollution & global warming. Under pressure from international environmental agencies, our government is committed to reduce its carbon footprint, lower its emission of green house gasses & reduce its dependence on thermal power plants by 2020. Indian coal is mostly of inferior grade (avg. gross calorific value is 4500 Kcal / kg, low carbon, high ash & sulphur content). So emission of green house gasses & coal consumption (0.7 kg / kWh) is much higher compared to USA, Australia or other EU countries.

As per guidelines by Ministry of Environment & Forests coal having ash content < 34 % is to be used. Coal washeries are being setup at the coal mine pithead, on own & operate basis. Old plants are being modernized with capacity increase from 60 – 220 MW to 600 – 800 MW, to improve efficiency, reduce pollutant emissions & power generation cost. Several large hydel projects having an installed capacity of about 14 GW are under construction. Rich reserves of good grade Uranium have been discovered in Tummalapalla belt & Bhima basin of Karnataka & existing nuclear plants are to be expanded by additional 11 units of 13.2 GW capacity. The Ganga delta in Sunderbans, Gulf of Khambat & Gulf of Kutch in Gujarat, are having average tidal wave heights of 2.97 m, 6.77 m & 5.23 m respectively due to variations in local topography like shelving, funneling etc. & are prospective tidal power plant sites. A 3.75 MW Durgaduani mini power plant project in the Sunderbans is currently under construction. A geothermal power plant of 2 MW is under construction in Puga, J & K. Other prospective sites are Chhumathang in J & K, Tattapani in Chhattisgarh, Cambay Graben in Gujarat, Manikaran in Himachal Pradesh & Surajkund in Jharkhand. Government is actively sponsoring & promoting RES projects for rural electrification / captive use. Domestic power consumption is being reduced by popularizing solar appliances.

4. CONCLUSION

The different types of power plants, related hazards & safety counter measures, current Indian scenario, including government policy & plans have been discussed. It is hoped that the information presented in this paper will be useful to the decision makers in the industry & particularly to those engineering students who are interested in joining this industry.

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Implementation Investigation of Factors for Enhancement in Productivity with Economic Conclusions

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Abstract: Productivity is of concern rather an extremely important concern for any manufacturing industry. Several ways of improving productivity are suggested in this paper. Paper explains various productivity parameters which improved in various sections of Industry under consideration. Areas of weak productivity identified which indulges heavy set up or operational cost identified and this paper suggests alternate ways of doing the same process which resulted in cost saving. Cost saving directly means increase in profit. This paper gives the details of all such processes which reflect in cost saving of company undertaken as case study.

Keywords: Productivity, Energy saving, Machining, Machine Shop, Cost Saving

1. INTRODUCTION

Productivity usually defined as a ratio between output and input. It is a fundamental concept considering this efficient and effective use of resources. Dealing with continuous competition, company not only needs to produce quality products but excellence production systems and management also plays an important roles. . The aim of study is to improve the productivity in manufacturing industry. The objective is to identify the defect of the company and create a better solution to improve performance. Various industrial engineering technique and tools is implementing in this study in order to investigate and solve the problem that occurs in the production.

1.1. Objectives of selecting parameters

- 1) Implementation of tools from industrial engineering in manufacturing industry.
- 2) Identification of defects in high frequency at workstations
- 3) Introduction of latest methods in same manufacturing firm.
- 4) Improvement of productivity in firm.

2. LITERATURE SURVEY

Piotr Tomaszews et al., 2006 identified and analyze the impact comparative productivity of given two projects. One represented an initial development stage while the other represents a subsequent and thus more matured development stage. Henri Juslen et al., 2007 examined whether or not a controllable task-lighting system that allowed people to select high lighting levels will enhance

productivity under real working conditions. Hannu Rantanen, 2001 found that internal obstacles form the only category of obstacles which is clearly under the control of the firm. **Carrino et al., 2007** studies the characteristic complications of GMAW processes, owing above to the large count of main variable values and to their inter-dependency, proposed all possible results by designing a fuzzy-logic-based scheme, where elements were dogged by preparing an artificial neural network (ANN).

Dimitrov et al. focus is put on the effectual utilization of 5-axis machining with the high-end CAD/CAM-systems for their tenacity of productivity and quality up gradation. The analysis of several case studies like their comparison between 3-axis machining and 5-axis cutting as a substitute possibility has been proposed.

Weston paper accounts on progresses that assurance such a step change, primarily in auto, aero and construction equipment industries with roll out to other subdivisions. It labels how integrated people, product, process and plant (ip4) virtual environments and innovative forms.

2.1 Company Analysis

As per the consolidated - Audited financial statement in the fiscal year of 2012, total overall operating revenue in the firm increased by 10.8%, from Indian Rupees 2, 739.07 tens of millions to Indian Rupees 3, 039.68 tens of millions. So that the operating results increases from Indian Rupees 166.4 tens of millions to Indian Rupees 194.11 tens of millions which got at 16.65% change in overall. Returns on its equity (Net income/Total equity) move up to 14.25% to 14.72%, the Return On Asset (Net income / Total Asset) moved from 3.64% to 4.07% and the Net Margin in Profit

(Net Income/Net Sales) went from 2.94% to 3.14% when measure up to to the same phase of last year. The Debt against Equity Ratio was 262.38% to 293.13% of last year.

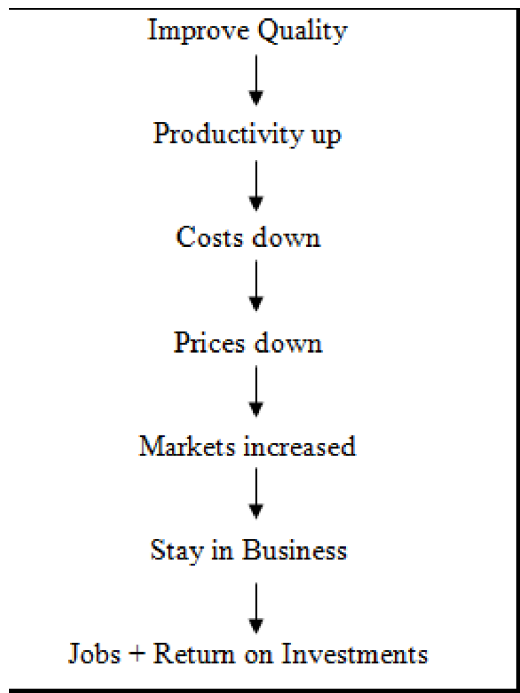


Fig. 1. Company Process layout

3. PRODUCTIVITY ANALYSIS:

3.1. Material Productivity: It is nothing but ratio between output and material input. Material Productivity becomes a key factor in economic production as given by:

$$\text{Material Productivity} = \frac{\text{Output}}{\text{Total material used as input}}$$

3.2. Labour Productivity: It is the ratio of output to human input or it may also be defined as ratio of total revenue from production to expenditure on labour.

$$\text{Labour Productivity} = \frac{\text{Total Revenue from production}}{\text{Expenditure on labour}}$$

3.3. Capital Productivity: It is the ratio of Turnover to Capital input.

$$\text{Capital Productivity} = \frac{\text{Turnover}}{\text{Capital Input}}$$

3.4. Machine Productivity: It is the ratio of output and Actual machine hours used.

$$\text{Machine Productivity} = \frac{\text{Output}}{\text{Actual machine hrs. used}}$$

3.5. Overall Productivity: It is the ratio of total output to the total input i.e labour input, material input, capital input and machine input.

$$\text{Overall Productivity} = \frac{\text{Total Output}}{\text{labour input} + \text{material input} + \text{capital input} + \text{machine input}}$$

4. PROCESS ANALYSIS OF SELECTED JOBS:

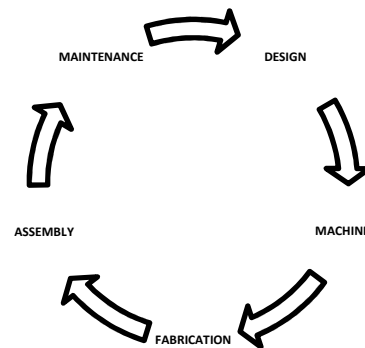


Fig.2. Selected Areas

5. ANALYSIS OF VARIOUS PROCESSES IN DESIGN SHOP

5.1. Pressure Relief Valve (Sand witch Plate Design) Replaced with Line mounted

In old method pressure relief valve is used. The drawing of which is shown below:

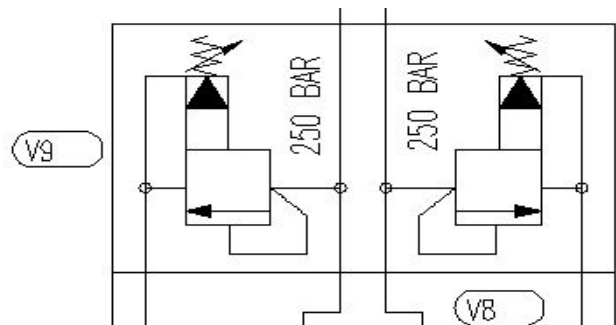


Fig. 3. Pressure Relief Valve

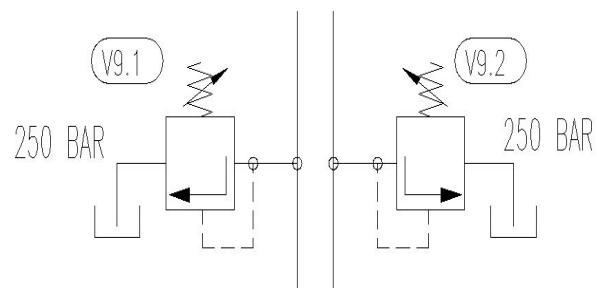


Fig. 4. Line Mounted Pressure Relief Valve (Edosomwan, 1986)

5.1.1. New Process Description:

Line Mounted Pressure Relief valves are used.

1. Easy maintenance, high reliability.
2. Less cost.

5.1.2. Total Saving:

1. 25 Mechanical Presses
2. 05 Hydraulic Presses
3. Cost of line mounted valves including pipe fittings (2 nos.) = Rs 3550 + 450 = Rs 4000
4. Annual Savings = $(05 \times 16450) + (27 \times 6705) - (32 \times 4000) = \text{Rs } 135000$

5.2. Inbuilt Lubrication Tank In Bottom Heads

In old method “separate lubrication tank” was used which was placed on ground. The drawing of which is shown below:

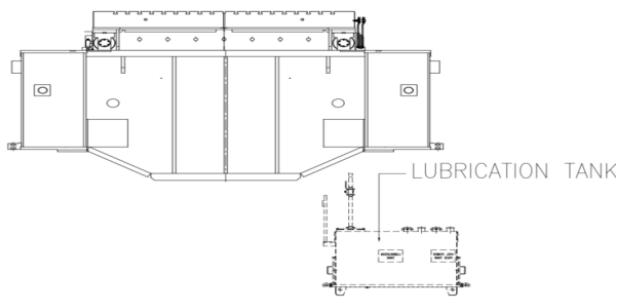


Fig. 5. Press showing separate lubrication tank

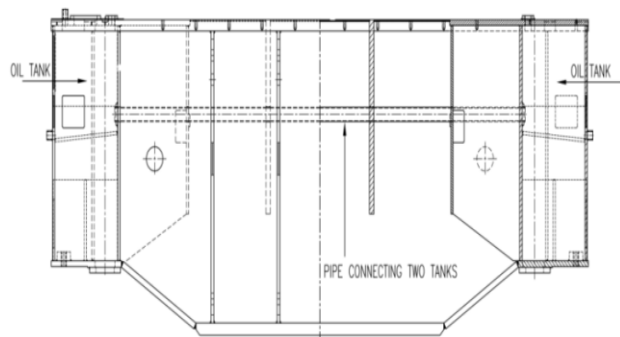


Fig. 6. Press showing inbuilt lubrication tank

5.2.1. New Process Description

1. Subject job did not have MB and Die cushion. So we have designed the lubrication tank inbuilt in bed fabrication.
2. We saved the separate fabricated tank.
3. Reduction in piping.

5.2.2. Total Saving:

1. Oil tank fabrication saved. (Rs. 70 per kg. for 725 kg weight of oil tank).
2. Net Savings = Rs 57750- 16800=40950 per press.
8Taking 2 presses annually, Total savings = Rs. 81900

5.3. Flange (Drive Shaft Assembly) Is Fabricated.

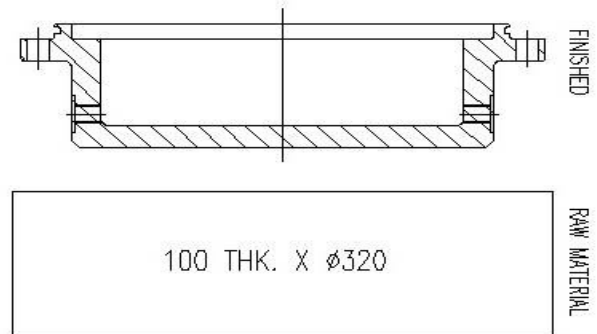


Fig. 7. Old Flange

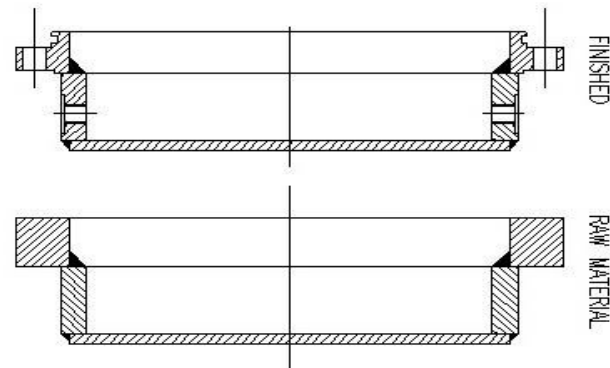


Fig. 8. New Flange

5.3.1. New Process Description:

1. Flange is machined from a fabrication.
2. Machining reduced to a great extent.
3. Fewer Raw Materials required.

5.3.2. New Cost Analysis:

1. Subcontracting Cost = Rs 3700 / piece
2. Subcontracting Machining Cost = Rs 1200 /piece
3. Subcontracting Material& Fabrication Cost = Rs 2460/pc
4. Total Subcontracting Cost = Rs 3660 /piece

5.3.3. Total Savings:

Annually (considering 25 presses annually) = Rs 6000- 3660
= $2340 \times 25 = \text{Rs } 58500$

5.4. Changes in Manufacturing Process Of Mechanical Press

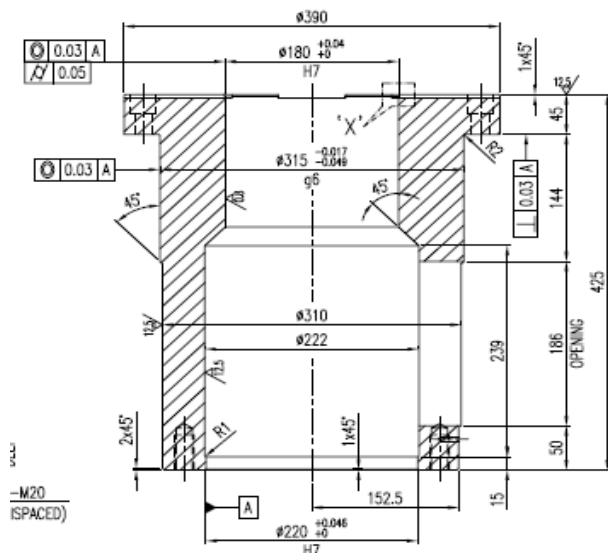


Fig. 9. Old Housing

5.4.1 New Method Description

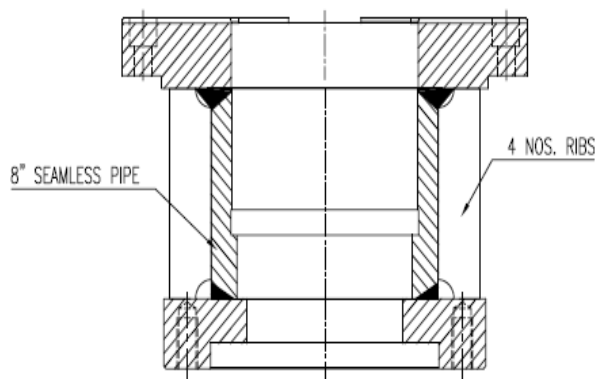


Fig. 10: New Housing

Now housing is made by fabricating top plate and bottom plate with seamless pipe.

5.4.2. New Cost Analysis:

1. Cost of fabricated components (Raw material) = Rs 8000
2. Fabrication cost = Rs 3000
3. Total cost per housing = Rs 11000
4. Cost of new plunger = Rs 3800
5. Cost saving per assembly = Rs 20500
6. On estimated 4 presses order annually

5.4.3. Savings:

Cost Saving (Annually) = Rs 326000

5.5. Design Change Of Hydraulic Presses

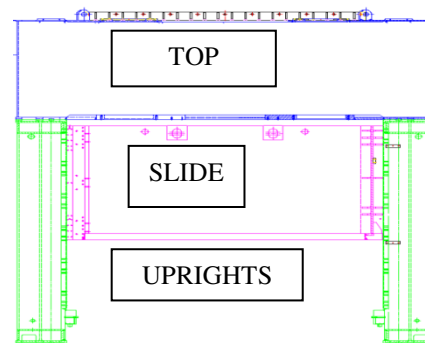


Fig. 11. Hydraulic Press

5.5.1. New Method Description

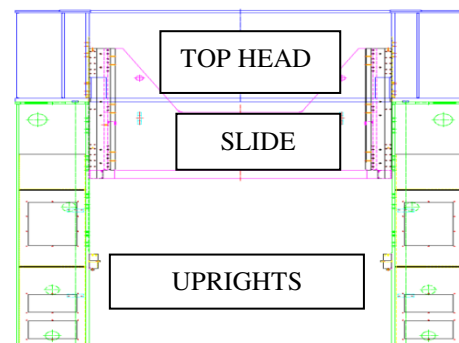


Fig. 12. Hydraulic Press

1. Guiding of slide is done with top head & upright.
2. Total Press height reduced.
3. Raw Material saved for tie rods & uprights.

5.5.2. Savings:

1. Tie Rod Length Reduced by 500 mm (480 kg per press saved)
3. Savings in Plates per press = $1080 \times 46 = \text{Rs } 49600$
4. Total Savings per press = Rs 92800
5. Annual Savings (Considering 10 presses annually) = Rs 928000

6. ANALYSIS OF VARIOUS PROCESSES IN ASSEMBLY SHOP

6.1. To reduce the cycle time in machining of the ecc. Gear & process simplification For assembly

Route of work change from previous stage to assembly shop

6.1.1. New Method Description:

1. Take the match marking from the flange
2. Drilling and tapping done

3. Reset the gear
4. Take match marking
5. Drilling and tapping done

6.1.2. New Cost Analysis:

1. Expected time with this process 20hrs.
2. In terms of rupees per press $20 \times 350 = 7000$

6.1.3. Savings:

Total saving in rupees 22600 per press per year saving : $5 \times 22600 = 113000$

6.2. Cycle Time Reduction in Stud & Nut Fitting On Crown In Intermediate Shaft Assembly.

6.2.1. New method Description:

A ring gauge of suitable thread in sizes m30, m32, m36, m42 is made & sent to vendor. It worked positively. Now there is no need to check or correct the threads by machining. Hence saving of assembly man hrs and machining hrs as well.

6.2.2. Savings:

Saving in labour cost = $3 \times 400 \times 40 = \text{Rs } 48000$
 Saving in machining cost = $4 \times 450 \times 40 = \text{Rs } 72000$

7. ANALYSIS AND RESULTS

1. While designing new Pressure Relief Valve here we able to reduce the cost up to Rs.135000 per annum.
2. In the installation of modified Inbuilt Lubrication Tank we able to compensate the cost in manufacturing almost Rs. 81900 annually.
3. Fabricating new flange (Drive Shaft Assembly), here able to reduce the design cost up to Rs. 58700 every year.
4. Acting changes in Manufacturing Process of Mechanical Press will able to reduce the design cost by Rs. 326000 per annum.
5. Changing and modifying the design Of Hydraulic Presses can reduce the design cost of setup with huge amount of Rs.928000 annually.
6. While incorporating the CNC Cutting Machine the machining time reduces from 1264 to 472 Hrs with net savings of Rs. 712800.
7. Saving of Rs 25600 as no time of filling and capping is required, so time energy reduces almost 64hrs.
8. Rs 4.45 Lac by considering new Display and Rs. 1.35 Lac by considering second hand display unit. This will able to help Floor Head to surveillance the

working and operations to labors and officials more precisely will improve the productivity and machine output to extent of 10% in total.

10. Saving in machining cost = $4 \times 450 \times 40 = \text{Rs } 72000$ per month and up to 4 hours per cycle.

So while taking the estimation, the total savings roughly come out to Rs 17, 81, 100 per annum which is almost 8% of the total expenses and 1326 hours of work energy saved by installing the new techniques.

8. CONCLUSION AND RECOMMENDATIONS

In ISGEC productivity increased by analyzing various processes in SHOPS:

1. Productivity increased in terms of time, capital, labour, material which can be seen from the result obtained above. It also shows the extent of benefits to the concerned company.
2. Improved productivity helped ISGEC to increase its turnover and to meet customers' order within time.
3. The productivity improved is sustainable in nature and further there is an ease of operation two in implementing the various suggested alternates manufacturing techniques.
4. Productivity can be improved further by Ergonomics as it directly enhances a worker's ability to carry out his operations on different machines.

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Mobile Payment Adoption in India: Challenges and the Way Forward

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Abstract: Over the last one and a half decades, mobile payments have achieved considerable commercial success worldwide. Mobile payments show huge potential and present a great opportunity. The immediacy of mobile payments, along with the portability of mobile devices, makes it possible for consumers to conduct commercial transactions in many situations in a rapid and comfortable manner. However, in spite of its potential, the adoption of mobile payment has been slow in many countries including India. Recent studies show that some issues are hindering consumer adoption of mobile payments. This paper aims to throw light on major challenges for consumer adoption of mobile payments in India and the way forward.

Keywords: Mobile payment, mobile devices, Mobile payment adoption

1. INTRODUCTION

Mobile payment (m-payment) is defined as “transfer of funds in return for a good or service, where the mobile phone is involved in both the initiation and confirmation of the payment” (De Bel and Gâza, 2011, p.12). The m-payment system is a significant component of an m-commerce service, because it makes an m-commerce transaction possible by dealing with the exchange of the financial values of mobile transactions. Prior studies suggest that mobile payment methods provide their customers with a number of advantages including location-free access, a wide variety of purchase possibilities, an easy alternative to cash payments and timely contact with their financial resources. As highlighted in the Ministry of Finance’s Committee report on Digital Payments published in December 2016, financial inclusion is one of the foremost policy challenges facing India today. As of 2014, approximately 53 per cent of India’s population had access to formal financial services. In this context, mobile payment can act as a key enabler for accelerating financial inclusion.

2. M-PAYMENTS GROWTH AND ADOPTION

Recently, m-payments have achieved considerable commercial success worldwide. Worldwide total transaction value in the “Mobile Payments” segment amounts to US\$224, 426m in 2017 showing an annual growth rate of 40.1% and for India, transaction value by m-payments is expected to show an annual growth rate (CAGR 2017-2021) of 138.7 % resulting in the total amount of US\$2, 572m in 2021. In the “Mobile Payments” segment of India, the number of users is expected to amount to 21.9m by 2021 (Statista research, 2017). The

major reason for the growth in India include rising smart phone penetration and internet access.

As such, mobile payment can supplement or replace cash, check, credit and debit cards in consumer daily purchase, and it can also serve as a means of entry to electronic accounts and payments. There is growing awareness that mobile payment supplies economic benefits to the society as it has significant lower costs than cash-based services and existing card payments (Arvidsson, 2014; Mallat, Rossi and Tuunainen, 2004). Furthermore, it can generate competitive advantage for enterprises via its ubiquity and convenience (Chen, 2008; Mallat, 2007). Hence promoting consumers’ usage of mobile payment services is of utmost importance for both Governments and marketers. However, Au and Kauffman (2008) find that although mobile devices are virtually ubiquitous around the world, the penetration of mobile payment has been uneven. For example, mobile payment has been popular in some developing countries where credit cards are not widely available and many people do not have bank accounts (OECD, 2012). Mobile payment adoption in developed countries exhibits different patterns too. Studies show that mobile payment has not been widely adopted in the U.S. (Hayashi, 2012; Pope et al., 2011). Japan and Korea are successful with mobile payment adoption (Amoroso and Magnier-Watanabe, 2012; Pope et al., 2011). Pope et al. (2011) studied mobile payment adoption in U.S., Singapore, Hong Kong and India and concluded that mobile payment is still at an infancy stage. According to the MasterCard mobile payments readiness index, no country has achieved a mainstream consumer acceptance, and we are still in the early days for the adoption of mobile payments globally (MasterCard, 2014). For a successful implementation of mobile payment

services, it is crucial to understand the challenges which stand in the way of m-payments.

3. METHODOLOGY

The methodology used for this study is based on secondary information available mainly from online publications by reputed bodies such as BGC-GOOGLE, EY, MasterCard, OECD and Ministry of Finance, GOI. Data has also been collected with the help of various articles, journals and websites.

4. CHALLENGES TO THE CONSUMER ADOPTION OF MOBILE PAYMENTS IN INDIA

4.1 Security Concerns and Lack of Trust in Mobile Payments

When innovative technologies such as contactless mobile payments are adopted, security becomes a vital issue (Loilier, 2013). There is a common consumer perception that mobile payments are insecure (Cyril et al., 2008). In mobile payment transactions, credit card number and care verification value code (CVV) are often transmitted. Wireless networks are vulnerable to attacks and mobile encryption systems are less robust than traditional encryption systems (Misra and Wickamasinghe, 2004). These security concerns increase users' perceived risk and decrease their usage intention toward such systems (Zhou, 2011). Though some security practices are in place, primarily using cryptography, there are no clear standards on protection of payment card information in such transactions from regulatory bodies. If security concerns are a major barrier to mobile adoption, it stands to reason that trust is a key component to overcoming that barrier. However, resolving security issues will not automatically help to gain this trust. It is of more importance, however, to convince the consumers about the security of m-payment systems. This can be done with the assistance of proper marketing channels as well as advocacy from reputable institutions.

4.2 Digital Literacy of Consumers

A large segment of the target population is not comfortable with the use of mobile technology and many consumers are facing English language barriers. Service providers will need to invest in simplifying the technology and interface, providing multilingual interfaces and more importantly, educating customers about using mobile technology (EY analysis, 2016).

4.3 Speed of Transaction

The speed of mobile payment transactions is still slow, especially at the POS, where consumers and merchant look for a quick turnaround. Moreover, in areas of poor connectivity, transactions often fail or time out. This results in a poor consumer experience, which dis-

incentivizes them from making mobile payments (EY analysis, 2016).

4.4 Complexity of Usage

Product complexity is considered to be one of the biggest reasons behind non-usage of digital payments (BCG-Google Digital Payments, 2020). As digital payments target heterogeneous user and merchant segments across the value chain, product design needs to ensure that the solution is built for the base and communicated appropriately. This is critical for universal acceptance. In comparison, cash is still the most preferred instrument of payment, simply because of its absolute ease of understanding even though it is not the most convenient option. Payment innovations have to ensure increasing simplicity of the product.

4.5 Habit to Use Cash

A large percentage of the Indian population is still habituated to cash even when making online purchases. Consumers also feel that spending money in cash aids in budget management and keeps spending patterns in check. Although they acknowledge that handling cash is inconvenient, they are satisfied with the way it works and are not enthusiastic about changing how they handle money very easily as it is so ingrained in their day-to-day life (Google-BCG Market study, 2016).

4.6 A Perceived Lack of Compelling Value Proposition

As per the market study by Google-BCG (2016), about a half of the users could not fully comprehend the benefits or value of using digital payments. It is evidenced in the fact that they have not heard a lot of people use or talk about digital payments. This does not give them a very strong motivation to alter behavior or adopt digital payments.

4.7 Inconvenience, Low Reach and Possibility of Making Mistake

According to the market study by Google-BCG (2016), consumers who have used mobile payments have indicated that inconvenience of remembering login credentials, insufficient acceptance of m-payments, possibility of a technical or human mistake during a transaction and frequently running out of balance are the top reasons for not using m-payments.

5. THE WAY FORWARD

In order to acquire customers to use mobile payments, certain key points need to be addressed by the payment service providers, regulators and government.

Triangulating information from multiple data points (such as customer and merchant transaction analysis, location, device fingerprinting and value-volume thresholds) can help in developing algorithms to contain risks and pre-empt frauds.

This will help build consumer and merchant trust in the system.

The m-payment offerings can be made more appealing through incentives such as tax rebates, waiver of transaction fees and charges to enable adoption. The user interface of m-payment solutions needs to be simple and intuitive to ensure a seamless customer experience. To drive mass adoption expanding merchant acceptance is critical. Acquisition and integration of merchants under the system would increase the use cases and thereby increase acceptance of digital payments.

Providers should focus on educating customers considering the low digital literacy and communicate the usage benefits clearly. To overcome English language barriers, specifically for customers from tier II and tier III cities, the providers should start offering multiple regional language interfaces. Prominent m-payment players such as Paytm and MobiKwik have already developed such interfaces.

To win back churned consumers, payment service providers need to address critical pain points. For example, introducing biometric authentication would eliminate the need of multiple user names and passwords. Auto-sweep features can aid in addressing low account balances and the maintenance of requisite minimum balances in the digital payment account.

High frequency transactions should be brought under the ambit of digital payments to urge consumers' movement in that direction. In order to make a decisive move towards a less cash society, it is imperative that transacting through electronic mode is as attractive as transacting with cash. In this regard, RBI can opt for designing a pricing strategy that would influence the payment behaviour of customers which encourages use of electronic products over cash and paper based products. Also there is a need for expanding the acceptance infrastructure such as ATMs, PoS terminals, micro-ATMs, handheld devices etc. Use of modern technology such as mobile PoS could be explored to cover the large base of retailers across the country.

A joint policy-making or go-to-market approach on mobile payments by the industry players, facilitated by payments bodies can help in expanding the market and increasing adoption. Such policy decisions for facilitating mobile payments can take into consideration the requirements of prepaid operators, banks and telcos for building and scaling up the infrastructure and transaction rails required for payments. The Government can possibly bring in restrictions that limit transactions done in cash beyond a defined threshold. The regulators and payments bodies also need to act as facilitators by taking initiatives such as standardizing merchant acceptance norms to simplify the merchant onboarding process.

6. CONCLUSION

Cash transactions continue to be the dominant form of payments, and users — especially from low-income groups — prefer cash to digital forms of payments. Getting customers informed about and comfortable with the new platforms will be pivotal to the widespread uptake of mobile payments in the country. The major challenges for Indian customers include security and trust issues, lack of digital literacy and language barriers, complexity of usage, lack of knowledge about the benefits of m-payments and high dependency on cash. India must learn from other countries in the developing world, which have managed to reduce their dependence on cash even while bringing in more people in the folds of the formal banking system. The success of mobile payments hinges on institutional initiatives, product and process innovation from operators, a supporting regulatory environment and channelized efforts of the industry players toward a common objective.

The path forward is clear:

- The government should invest in building the required financial and digital infrastructure
- A nationwide financial and digital literacy campaign accompanied by a medium-term strategy to improve access to, and awareness of, electronic payments. Targeted financial education programmes can improve financial skills and credit management, and increase account ownership
- The government must undertake the herculean task of changing attitudes towards digital payments among customers and merchants.
- Regulators should put in place all necessary cyber security measures and providers of m-payments should develop easy to use, flexible and multilingual m-payment solutions to cover customers from all segments.

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Use of Big Data tools in PLM

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Abstract: Most large enterprises store a tremendous volume of transactional data, trillions of information consisting of customer details, suppliers and data related to different phases of product life cycle management. There is an exponential growth in amount of data. To overcome these complex data much work is being carried out. The main aim of this paper is to highlight Big Data tools that can be used during the various data involved in three phases of product lifecycle management. The paper also describes the advantages of Big Data tools (Hadoop) in product lifecycle management.

Keywords: Big Data, Product Lifecycle Management.

1. INTRODUCTION

Nowadays data is being produced on a large scale from different sources. The different sources may be manufacturing industries, banking sectors, health organizations, transportation and logistics, government systems, education systems etc. This data needs to be stored at some particular location so that it can be retrieved efficiently whenever needed. Before introduction of Big Data, the companies were not able to store tremendous data for longer periods because of limited data storage capabilities, which would force them to delete the previous data (Ahmed et. al., 2017).

International data corporation stated that service sector and manufacturing sector both created over 1600 Exabyte data during the year 2015. The data volume is generated at a rapid speed because of the digital revolution and advancement of information technology such as ubiquitous –sensing mobile devices, aerial sensory techniques, Internet of things (IoT) Technologies, microphones, cameras and wireless sensor networks (Zhong et. al., 2016). Such datasets are huge and unstructured, ambiguous. Therefore it is a difficult task to handle these data using traditional database management systems.

2. ABOUT BIG DATA

“Big Data” refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze. The given definition is subjective which incorporates moving information of how big a dataset needs to be in order to be considered Big Data –i.e. the Big Data is not defined in terms of being larger than a certain terabytes of data. We consider that, as there is advancement in technology, the size of datasets that qualify as Big Data will also increase (Manyinka et. al., 2011).

2.1 Characteristics of “Big Data”

“3Vs”, which is generally accepted three defining dimensions of “Big Data” were introduced in the year 2001

viz. ‘Volume’, ‘Velocity’ and ‘Variety’. Two more “Vs” are introduced nowadays, ‘Variability’ and ‘Value’ (Jingran et. al., 2015).

- Volume: huge amount of data is produced per second. “Big Data” is capable of storing this data (certain no of terabytes) which is referred to as Volume
- Velocity: Data is being generated fast and it is need to be stored fast. If the processing time of system increases then decision taking time will also increase which will lead to miss opportunities.
- Variety: The data which is getting generated may be of different formats, types and structure this variation of data is referred to as variety.
- Variability: Expansion in the range of values of data is referred to as Variability. The difference between Big Data and traditional datasets is that traditional datasets always represent low variance than Big Data.
- Value: While feeding the data in the systems it is important to know that which data is important and which is to be not recorded. Valued information can be produced and can be used in business operations by using data analytic methods. This is referred to as Value.

3. ABOUT PLM

A strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life—integrating people, processes, business systems, and information (Jingran, et al, 2015). Product Lifecycle Management (PLM) is the business activity of managing, in the most effective way, a company's products all the way across their lifecycles. Product's lifecycle includes the data related to the idea of

the product, the data when it is being defined, the data when it is being realized, the data when it is used and when it is to be disposed of (Arbor, 2002).

Three of the lifecycle phases (Imagination, Definition and Realization) make up the Beginning-of-Life (BOL) of the product. There is a Middle-of-Life (MOL) phase which includes activities such as product use, support and maintenance. There is an End-of-Life (EOL) phase which includes activities such as product retirement, disposal and recycling (Jingran, et al, 2015).

4. PHASES OF PLM

As discussed above in the introduction of PLM the different stages of product lifecycle management are as follows

- BOL(beginning of life)
- MOL(middle of life)
- EOL(end of life)

4.1 Beginning of Life

In order to develop a new product in market, planning is done well before the production. The data in the beginning of life consists of idea generation, idea evaluation, feasibility analysis, technical research and development, product (market) research and development, preliminary production, market testing, commercial production, product introduction.

TABLE 1: Data in Beginning of Life

Category	Main data	Category	
Customers' demands	Product function, configuration, packaging, quality, cost, brand, and other related expectation Design	Design specifications	Materials list, suppliers list, electronic drawings, computer programming codes, configuration parameters, location parameters, tolerance parameters, intensity of materials, etc.
Maintenance and failure Information	Main breakdown problems, frequency of maintenance, failure rate, critical component list, root causes, etc.	Production information	Assemble instruction, production specifications, production history data, production plan, inventory status, etc.
Cooperative corporation Information	Alternative supplier information, alternative outsourcing company information, etc.		

4.2 Middle of Life

After the product is launched in the market, the attention should be focused on the service. Middle life of product consists of data related to logistics, distribution, use, service and maintenance.

TABLE 2: Data in Middle of Life

Category	Main data	Category	Main data
User manual	Product function introduction, installation guide, use condition, precautions, etc.	Product status Information	Degree of quality of each component, performance definition, etc.
Production Information	Assemble instruction, production specifications, production history data, production plan, inventory status, etc.	Usage environment Information	Usage condition (e.g., average humidity, internal/external temperature), user mission profile, usage time, etc.
Maintenance supporting information	Spare part ID list, price of spare part, maintenance/service instructions, etc.	Maintenance Plan	Maintenance engineers, tools, dates, places, costs, failure causes, etc.

4.3 End of Life

After the product is put into service, it eventually wears out or becomes obsolete because a better product comes into the market. At this stage one option is to junk the part and dispose of it in some way that eventually returns the

material to the earth. This data related to the product's disposal is involved in the end of life of product. By knowing the history of information of maintenance usage environment information and product status information from middle of life degradation status and value of individual components can be calculated.

TABLE 3: Date in End of Life

Category	Main data	Category	Main data
Maintenance history Information	Components' IDs in problem, installed date, maintenance engineers' IDs, list of replaced parts, aging statistics after substitution, maintenance cost, etc.	Recycling part information	Reuse part or component, remanufacturing information, quality of remanufacturing part or component, etc.
Product status Information	Degree of quality of each component, performance definition, etc.	EOL product status information	Product/part/component lifetime, recycling/ reuse rate of each component or part, etc.
Usage environment Information	Usage condition (e.g., average humidity, internal/external temperature), user mission profile, usage time, etc.	Dismantling information	Ease to disassemble, reuse or recycling value, disassembly cost, remanufacturing cost, disposal cost, etc.

5. BIG DATA TOOLS (HADOOP) APPLICATIONS IN PLM

Traditional technologies lag behind in providing high performance and capabilities of processing data quickly. Hadoop fills a gap in the market by effectively storing and providing computational capabilities over substantial amounts of data. Hadoop rapidly processes large data sets by using its parallel clusters and distributed file system. There is no load on network and servers as Hadoop performs its task where data are stored whereas the traditional technologies copy in memory all distant data to perform executions. Hadoop consists of fundamental units viz. Hadoop Distributed File System (HDFS), MapReduce framework and YARN (Yet Another Resource Negotiator)(described in the following sections).In addition, modules can be added by the users according to their requirement e.g. capacity, performance, reliability, scalability, security etc.

5.1 Data Storage Using Distributed File System:

Storing Big Data in any system was a problem. Thus Hadoop came up with Hadoop distribution File System to solve this problem. The Big Data which is to be stored in the master system is divided into multiple churns of data in different slave systems. HDFS has two main daemons one is NameNode and the other is Data node. Namenode is a master daemon which runs on the master machine that is of

high end essentially and Data Node is a slave machine which runs on the commodity hardware. There can be one NameNode and multiple DataNode. NameNode records the metadata (location of blocks stored, size of the files, permissions, hierarchy etc). It receives time to time reports from the DataNode. Thus it manages the Data Nodes. Data Nodes are the slave daemons which store the actual data, it serves read and write requests from the clients. The slave machine is connected to the master machine by core switch at the same time the slave machines are interconnected. Each file is stored in HDFS as blocks as it is a distributed system. Hadoop creates replica of each block that get stored into the Hadoop File Distribution System thus it is a tolerant system (Ahmed et. al., 2017).

5.2 Data Processing using MapReduce:

MapReduce is a programming for data processing. Different language programs such as Java, Python, and Ruby etc can be written in MapReduce. The programs written in the MapReduce are parallel. The processing in the Map Reduce is broken in two phases: the Map phase and Reduce phase. The programmer also specifies two functions the map function and reduce function.

Map function: The input data (long text files) is divided into independent data partitions constituting key-value pairs.Mapper processes each key value-pairs individually and tasks Across the master controller.Unique compute

node is assigned to each data partition. At this stage, the framework is charged to collect all the intermediate key-value pairs, to sort and group them by key.

Reduce function: The intermediate output data is processed by the Reduce function. The reduce function combines key-values working with one key at a time. Later it finds the average of values given in by the mapper. Then it produces list of output Key-value pairs and finally these output Key-value pairs are stored in the output file.

For scheduling purpose, the NameNode runs a instance called JobTracker. It sees whether slave nodes have assigned tasks or not. If not then it reassigns the task. Similarly the slave nodes run the TaskTracker instance which will work same as the JobTracker works for the master nodes (Ahmed et. al., 2017).

5.3 Data Processing Using YARN:

YARN (Yet Another Resource Negotiator) is a core component of Hadoop 2.0 and it is added to provide improved performance in the Hadoop world. YARN is next generation of the Hadoop computing platform which offers various advantages compared to MapReduce in first version of Hadoop. YARN/MapReduce 2.0 is introduced in the Hadoop 2.0. It is a layer that separates the resource manager layer and processing component layer. MapReduce 2.0 moves the resource manager (like infrastructure to monitor nodes, allocates resources and schedule job) into YARN.

JobTracker responsibilities in MapReduce 1.0 is now split into two daemons in YARN/MapReduce 2.0

Resource manager: It manages the resource allocations in the Hadoop cluster. Resource manager consists of two components –scheduler and application manager. Resource manager is a global resource scheduler which manages and allocates cluster resources. It is responsible for tacking the resources and also scheduling the applications.

Application Master: Manages application life cycle and task scheduling. It can interact with the resource manager as well as the Node Manager. Application is job submitted to the framework.

YARN is a more isolated and scalable model than the MapReduce 1.0 system where a single JobTracker does all the resource management, scheduling and task monitoring work (Ahmed et. al., 2017).

6. ADVANTAGES OF BIG DATA TOOLS IN PLM

Improving the quality and innovation of design of product: Quality and innovation in the product design can be improved by using Big Data tools. Most of the companies today believe in market driven supply chain. They are serious about the customer service. the companies want feedback from the customers so that they come to know what the customers want . Thus the customers get

involved in the design phase. For example, Xiaomi Company in China is a typical successful representative (Arbor, 2002).

Improving the accuracy, quality, and output of production: Nowadays most of the companies are being fully automated. Once the raw material enters the industry all the remaining processes are performed by CNC machines. Therefore these CNC machines produce a large amount of data in very less time. Big Data tools help to store this Data accurately.

Accurately forecasting product demands: By conducting surveys the customer needs can be predicted. Big Data tools helps in carrying out such surveys knowing the customer needs. By collecting this data using Big Data tools like Hadoop forecasting can be done, which may prove efficient for any industry

Data Storage in PLM: Storing large data involved in the various phases of product lifecycle management is now possible by using the Big Data tools. The data stored is secure and can be retrieved very fast, as the processing speed of Big Data tools is very fast. Manufacturing companies store a large amount of product related data. They use this data for in their new projects so it is essential for them to store it securely, which is done by using Big Data tools.

7. CONCLUSION

Big Data has emerged as an element which is able to provide solutions for handling the tremendous data. Big Data tools (Hadoop) can be used in the different phases involved in the product lifecycle management. Big Data tools can be proved to be efficient for industries as it is very economical. Certain Big Technical giants use this technology and in future Big Data tools will be used almost by all companies.

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The Internet of Things in Product Life Cycle Management

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Abstract: *The Internet of Things belongs to the ever growing network of physical objects which feature an IP address for internet connectivity, and communication that occurs between these objects and other Internet-enabled devices and systems. IoT has attracted lots of attention from all over world recently. It is a system where daily used objects can be equipped with, sensing, identifying networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to accomplish some objective. Successful applications of IoT have been implemented in many fields. Today, expectation from Internet of Things (IoT) is extremely high worldwide. Internet of Things can provide a good opportunity to build a powerful industrial system; also it can be used in PLM industries. A wide range of industrial application have been developed and deployed in recent years. This paper reviews the concept of Internet of Things (IoT), important technology in IoT, major application of IoT. Moreover it discusses concept of Product Lifecycle Management (PLM), application of Internet of Things (IoT) in Product Lifecycle Management.*

Keywords: *Internet of Things (IoT), Product Lifecycle Management (PLM), RFID, Closed loop PLM, Mechanical Engineer.*

1. INTRODUCTION

Internet of Things (IoT) refers to the strong connectedness between digital and physical world. Over last couple of decades, there is a continuous evolution in the Internet of Things technology. IoT has implemented in many areas. The term IoT was initially proposed to refer for uniquely identifiable interoperable connected object with Radio Frequency Identification technology (RFID). As Internet of Things technological revolution continues to take hold of industries worldwide such as energy manufacturing, healthcare services, and transportation, industry leaders are looking for ways to gain the analytical insight that IoT technology promises.

Product Lifecycle Management (PLM) is a new paradigm for manufacturing companies. As its name describes, Product Lifecycle management allows companies to manage their products across their lifecycles – from the basic idea for a product to the end of its life. This is one of the most important activities in any manufacturing company. Successful applications of IoT have been demonstrated in many fields. New technologies enable the IoT in the world of Product Lifecycle Management (PLM) to bring digital product and digital manufacturing to the next level.

In order to become smart, manufacturing industries need to employ new intelligent methods of production and target a marketplace in which real time information is exchanged between products and machine services.

With IoT technology, the PLM process continues out into the field, allowing all stakeholders in the product's lifecycle from initial design, in manufacturing of product to gain visibility into how the product is performing and being used by its customers. In this paper the concept of IoT as well as PLM introduced and the successful application of IoT in Product lifecycle Management (PLM) system is analyzed.

2.1 Concept of IoT

The term “Internet of Things” (IoT) was first proposed in 1999 by British technology pioneer Kevin Ashton in MIT's Auto ID centre, a global research network of academics laboratories focused on RFID and IoT technology. Internet of things (IoT) is defined as the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data (Navid, 2016)). IoT can be considered as a global network infrastructures composed of numerous connected devices that depends on sensory, communication, networking and information processing technology.

The basic technology for IoT is Radio Frequency Identification (RFID) technology which allows microchips to transmit the identification to readers through wireless communication. By using RFID readers peoples can identify, track and monitored any object attached with RFID tags automatically. Another foundational technology for IoT is wireless sensors network (WSNs), which mainly use interconnected intelligent sensors to sense and monitoring. The advancement in both RFID and WSN significantly contribute to the development of IoT. Today, the Internet of Things has become a famous term for

describing scenarios in which Internet connectivity and computing capability extend to a variety of objects, devices, sensors, and everyday items.

There is no universally accepted definition for the term IoT. Different definitions are used by various groups. Here we consider following definition of IoT among several.

“The term “Internet of Things” (IoT) denotes a trend where a large number of embedded devices Employ communication services offered by the Internet protocols. Many of these devices, often

Called “smart objects, ” are not directly operated by humans, but exist as components in buildings or

Vehicles, or are spread out in the environment.”

2.2. Characteristics of IoT

Gathering from existing reports and research documents, the characteristics of IoT are concluded (kavyashree G Chandrasekhar, 2016).

2.2.1. Intelligence

IoT comes with combination of algorithms and computation, software and hardware that makes IoT smart. Ambient Intelligence in IoT enhances its capabilities which facilitate the things to respond to in an intelligent manner to a particular situation and support them in carrying out specific operation.

2.2.2. Connectivity

Connectivity empowers Internet of Things by bringing together everyday objects. Connectivity enables network accessibility and compatibility in the things. Intelligence in IoT enhances its capabilities which facilitate the things to respond to in an intelligent manner to a particular situation and support them in carrying out specific operation.

2.2.3. Dynamic nature

The primary activity of IoT system is to collect data from its surrounding environment; this is achieved by the dynamic changes that take place around the devices.

2.2.5. Sensing

IoT would not be possible without the use of sensors which will detect or measure any changes in the environment to generate data that can report on their status or even interact with the surroundings.

2.2.6. Heterogeneity

Heterogeneity in IoT is one of the important characteristics. Devices in IoT are based on different hardware platform

and networks and can interact with other devices or service platforms through different networks.

2.3. IoT's Key components

2.3.1. Things

Things are smart, connected products and other. Things combine processors, sensors and software with connectivity.

2.3.2. Communication infrastructure

Communication infrastructure includes wired or wireless (Wi-Fi, 4G, Bluetooth and LAN) network connects things to the internet and each other.

2.3.3. Computing infrastructure

Data capture and analytics tools, and new business and software applications create new forms of value.

2.4. Applications of IoT

Although IoT is an emerging domain, it did help a lot to enable or enhance countless applications, which has brought numerous changes into our daily lives. According to the survey that the IoT-I project ran during 2010, 65 IoT application scenarios were identified, grouped in 14 domains: Transportation, Smart Home, Smart City, Lifestyle, Re- tail, Agriculture, Smart Factory, Supply chain, Emergency, Health care, User interaction, Culture and tourism, Environment and Energy. The major 54 applications in 12 domains of IoT are illustrated in fig. 2.1.

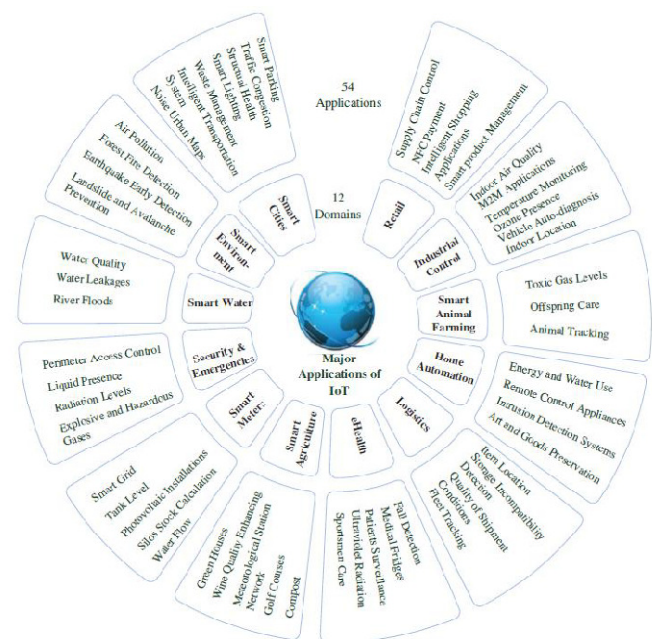


Fig. 2.1 Major application of IoT (Fei & Y, 2016)

3. PRODUCT LIFECYCLE MANAGEMENT (PLM)

3.1. Concept of PLM

PLM manages the all product data from conceptualization to finished product. PLM is a strategic approach and has three fundamental dimensions: (i) universal, secure, managed access and use of product definition information, (ii) maintaining the integrity of that product definition and related information throughout the life of the product or plant and (iii) managing and maintaining business processes used to create, manage, disseminate, share and use the information. In order to face the new industrial challenges such as environmental changes (mass customization, short product development lead time, high complexity of product functions), increasing collaboration (intra-enterprise, extended supply chain), importance of growth of Web based paradigms and technology, digital manufacturing, customer service as well as decision support services, the information loops along the whole product lifecycle have to be closed. The stakeholders have a general desire to enable the seamless flow, tracing and updating of information about a product, after its delivery to the customer and up to its final destiny (decommissioning, deregistration and EOL) and back to the designer and producer (Kiritsis, 2009).

3.2. Benefits of PLM

PLM provides benefits throughout the product lifecycle. Examples include getting products to market faster in the Beginning-of-Life, providing better support for their use during the Middle-of-Life, and managing their End-of-Life better.

With its focus on the product, companies are looking for PLM to provide benefits in four main areas shown in fig 3.1 (Stark, 2005).

4. THE INTERNET OF THINGS AND PRODUCT LIFECYCLE MANAGEMENT

For product development process the product data management and information technology based PLM are central concept. The concept of PLM can be considered as an evolution of product data management, so we can say that concept of PLM is derived out from PDM.

PLM is strategic approach which considers a product over its entire lifecycle. Each lifecycle phase consists of particular rules, production and information set which are required for lifecycle phases. The Product lifecycle can be divided into three phase as following.

BoL- Beginning of life (BoL) phase contains the conceptualization, design and production of product. First an idea or concept is developed then product concepts and their implementation and verification are developed.

MoL- In Middle of Life phase product is used by customers. In this phase challenge is to understand the consumer and to maintain and/or repair product.

EoL- When the product is eventually withdrawn from market, the End of Life phase is started. Generally the product is returned to the manufacturer to disassemble and recycled. The details of product parts and material can be used again.

During all these three phases the large amount of data is produced and maintaining and controlling of these data is difficult. Product data generated during MoL and EoL can use as feedback for designing a new product for generating conceptualization and design. IoT approach in PLM is can applied at all three phases of Product during its life. There is a general requirement of many stakeholders in the product supply and value chain (from designers to users and recyclers) to enable the seamless flow, tracing and updating of information about a product, after its delivery to the customer and up to its final destiny (decommissioning, deregistration and EOL) and back to the designer and producer. This is illustrated in fig. 4.1, where dashed thick lines represent material flow along the product lifecycle including 'recycling' loops, while dotted lines represent information loops (Kiritsis, 2009). The objective here is to allow information flow management to go beyond the customers and to close the product lifecycle information loop and enable the seamless e-transformation of product lifecycle information to knowledge.

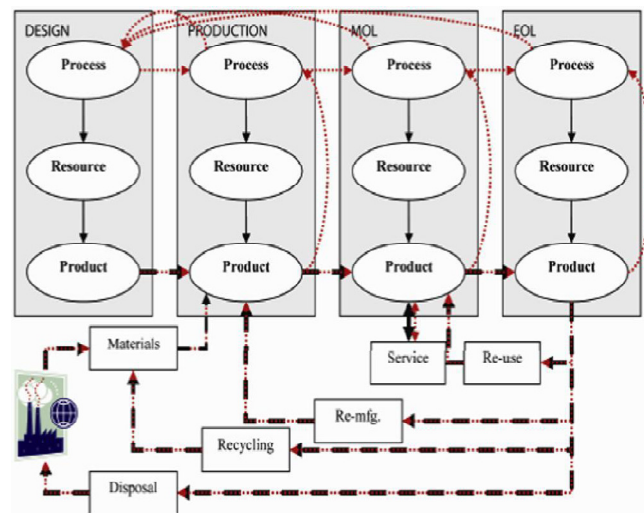


Fig. 4.1 Feedback of MoL and EoL for new product (Kiritsis, 2009)

During production, by collecting and analyzing data by sensors embedded in products and systems, organizations can start to optimize use and production, determine if particular parts has started to fails, and if the product or

piece of equipment is operating in the field as it was designed to.

Manufacturers have already started investing in hardware, software, and networking systems across the world and developing strategies to build the Internet of Things (IoT) and Services architecture to capitalize upon its benefits.

Among IT applications in digital factory, PLM is critical for the integration and management of information. PLM is important for the integration and management of information. Hence we use a PLM system to represent the digital factory in this work. Figure 4.2 illustrates our system architecture for the integration between the 'IoT platform' and 'PLM'. The role of the PLM system is to collecting and managing data of products, processes, definitions, resources and decisions across the whole product lifecycle supporting changes and enabling traceability of these changes. The IoT layer is used to collect large amounts of real time data, normally used for monitoring, controlling and planning on the shop floor. The real time information comes from various sources such as temperature pressure sensors or machine controllers. The difference between the IoT layer and the PLM layer is the database type to store data. Unique identifiers of products or parts are important for the PLM application during the lifecycle because products in PLM are used not only inside the enterprise but also in a distributed and collaborative environment.

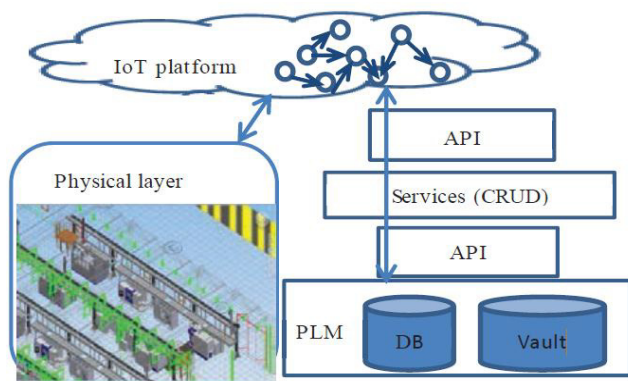


Fig- 4.2 System architecture of IoT based Factory
(Navid, 2016)

In the IoT layer large amounts of data are collected and stored in an unstructured way and in real time databases.

In Middle of Life; Until a moment ago, PLM technology only continued through the lifecycle until the product rolled off the production line and was put into use. This meant that any failures or issues that occurred had to be manually reported by the customer themselves.

Now using IoT, the PLM process continues out into the field, allowing all stakeholders in the product's lifecycle to gain visibility into how the product is performing and being

used by its customers – without waiting for customers to volunteer this information. Engineers are able to automatically make crucial edits to the product that manufacturing can begin integrating immediately. By monitoring product the minor issues can be spotted and fixed before they grow into large issues that can halt the product's use causing downtime that can severely affect customers' bottom lines. By using IoT we can stay connected with product and monitor product using sensors. By monitoring the product in the field, minor issues can be spotted and fixed before they grow into larger issues that can halt the product's use.

In End of Life (EoL), PLM systems can predict remaining lifetime of parts and components based on usage data generated by IoT. Predicting remaining lifetime of parts or components: In most cases, while a product cannot be used any longer, different level components still have value. Predicting remaining lifetime of parts or components helps to decide what to recycle and what the re-cycle level it should be. The combination of sensors and their autonomous coordination and simulation based on IoT will help to predict the occurrence of breakdown and the relatively accurate remaining lifetime of parts or components by analyzing history data combining with corresponding component ID.

IoT and PLM system will allow all the actors who play a important role during the lifecycle of a product (i.e. managers, designers, service and maintenance operators, recyclers, etc.) to track, manage and control product information at any phase of its lifecycle (i.e. design, manufacturing, MOL and EOL), from any place in the world and at any time.

Integrating IoT with PLM, many companies are adding sensors to new or existing products stationed everywhere in field or on factory floors to in a customer's house or working area, or even on the move with fleets and cargo. Using the data produced from sensors and IoT, PLM software is helping companies and manufacturers to monitor product for its entire lifecycle.

We can collect data from a fleet of similar smart products that are distributed all over the world, and we can collect data from each unique combination of dissimilar assets that we can find gathers you find together.

5. CONCLUSION

The IoT has gained significant attention over the last few years. With the advances in sensor hardware technology and cheap materials, sensors are expected to be attached to all the objects around us, so these can communicate with each other with minimum human intervention.

Also IoT and PLM are today's fastest growing technology which will have great impact on future product. IoT has

demonstrated successful application in many fields. Product lifecycle management is establishing new industrial standard for managing company's product. By combining IoT with PLM we stepping closer to next industrial revolution.

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Atzori et al., 2010; Sterling, 2005; Internet Reports, 2005

Standardization of Material Handling Process through VSM and VSD Approach – A Case Study

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Abstract: This research work is done to solve the very crucial and live problem of material handling process of various firms. Previously, the firms were working with presumed and gut-feeling values of the people involved in material handling process. Therefore, this research work was to replace the method with more robust and reliable method through the use of various literature and analysis.

The major aim of the research work is to map the current material handling process using value stream mapping (VSM) tools and also to increase productivity in warehouse as well as production. So a proposed process design was developed with the help of value stream design to eliminate nonvalue added activity in the process. Last but not the least, research work also involved time and man power savings in material handling process.

Keywords: Value Stream Mapping (VSM), Value Stream Design (VSD), Process Activity Mapping, Brought Out Parts (BOP), Standardization, Material Handling Unit (MHU)

1. INTRODUCTION

Warehouse management has retained its high demand in today's scenario despite the evolving supply chain management optimization techniques like lean manufacturing and just-in-time (JIT) techniques. Traditionally, warehousing was regarded as a waste in a logistics network. However, some warehouse and distribution facilities are being asked to go beyond simply stock inventory. Manufacturing and warehouse facilities are merging together to create cohesive units that are flexible to the changing requirements of the customer. Warehouse facilities are being asked to assemble, package, and ship inventory in some industries. The inventory could be raw material, work-in-process (WIP), or finished goods. This study is to review & understand the difficulty of handling, storage & issue of material. The firms which have probably the widest range of product families, the main problem for these plant maximum suppliers supplying parts in nonstandard packaging & most of the parts received in poor condition. All these components are repacked/repalletized in the Plant to store or to service it to the production line. In such a condition it is quite difficult task for store team all components in proper condition.

The major aim of paper is to define proper weight standard of material packets & define standard quantity for all components. Also aim of the paper is to define identification standard for each component & ensuring that should be feasible for line & easy for accountability.

The objective of the paper is to design standard material handling unit to ensure that material received from the

supplier can be stored as it is and can also be serviced on the production lines as it is.

The other objectives of paper are given below:

- Define packaging for BOP considering weight & qty to have minimum impact on cost
- Quality of material handling unit to be improved to avoid damages during transit
- To make storage more visible, easy to identify & easy to handle the components
- Proper identification for all incoming BOP
- Reduce no of man power used for material handling
- Standard material handling unit size for brought out part

The deliverables of research work are given below:

- Reduce manual handling activity inside store
- Eliminate NVA activity where ever possible
- Reduce Material handling casual from 14 to 8
- Improved Quality of storage

The rest of this paper is organized as follows. Section 2 briefly reviews the literature on. Section 3 presents the proposed method for. Case study is conducted and described in Section 4. Furthermore, discussion on future aspect is described in section 5. Finally, conclusions are presented in Section 6.

2. LITERATUREREVIEW

Warehousing and material handling remain important areas in the supply chain of organizations today. Organizations are focusing on their logistics strategy in order to reduce costs and better serve customers. According to the 2003 Survey of Career Patterns in Logistics conducted by Bernard J. La Londe and James L. Ginter of Ohio State University, the importance of warehousing in logistics has been growing in the 1990s and into 2003 (p. 12). A number of researchers demonstrated about the material handling process. The material handling practices of warehouse and distribution facilities can have a significant impact on overall profitability for an organization. Warehousing represents the largest operational cost in the supply chains of organizations (Vega, 2004). It can represent 2 to 5 percent of the costs of sales of a corporation (Frazelle, 2002b, p. 3). Thus, an emphasis on material handling in warehouse can help the bottom line of a company. The efficient use of space, equipment, and labor in the warehouse is an utmost concern for organizations looking to trim distribution costs. Fast and efficient movement of large quantities of raw materials, component parts and finished goods through the warehouse, coupled with timely and accurate information about the products being stored, are the goals of every logistics system. These goals have received increasing attention from top management of many organizations.

There are three basic functions of material handling process:

- a) Movement
- b) Storage
- c) Visual Management
- d) Packaging Process

2.1 Movement: Recently, the movement function has been receiving the most attention as organizations focus on improving inventory turns and speeding orders from manufacturing to final delivery.

The movement function can be further divided into several activities, including:

- Receiving
- Transfer or Putaway
- Order picking / selection
- Shipping

2.2 Storage: It can be performed on a temporary or semi-permanent basis. Temporary storage emphasizes the movement function of the warehouse and includes only the storage of product necessary for basic inventory replenishment. Temporary storage is required regardless of the actual inventory turnover.

Semi-permanent storage is the storage of inventory in excess of that required for normal replenishment. This inventory is referred to as buffer or safety stock.

2.3 Visual Management: It occurs simultaneously with the movement and storage functions. Management always need timely and accurate information as it attempts to administer the warehousing activity. Information on inventory levels, throughput levels (i.e. amount of product moving through the warehouse), stock keeping locations, inbound and outbound shipments, customer & supplier data, facility space utilization and personnel is vital to the successful operations of a warehouse.

It is important to eliminate any inefficiency in movement, storage and information transfer within the warehouse. The information derived from bar code tracking can also be used to generate and electronically transmit an Advance Shipping Notice (ASN).

2.4 Packaging process: It is often a multi-step operation that involves several different workstations or areas. Once considered the back-end of the operation, there is a growing recognition that packaging and shipping play an integral part in achieving high levels of customer service. In fact, many companies now consider these functions to be the key elements in streamlining the flow of products and information through the distribution chain. Packaging has a significant impact on the cost and productivity of logistics. Automating many of these steps can greatly improve throughput and avoid errors.

3. METHODOLOGY

The research work has following four phases.



Fig. 3.1

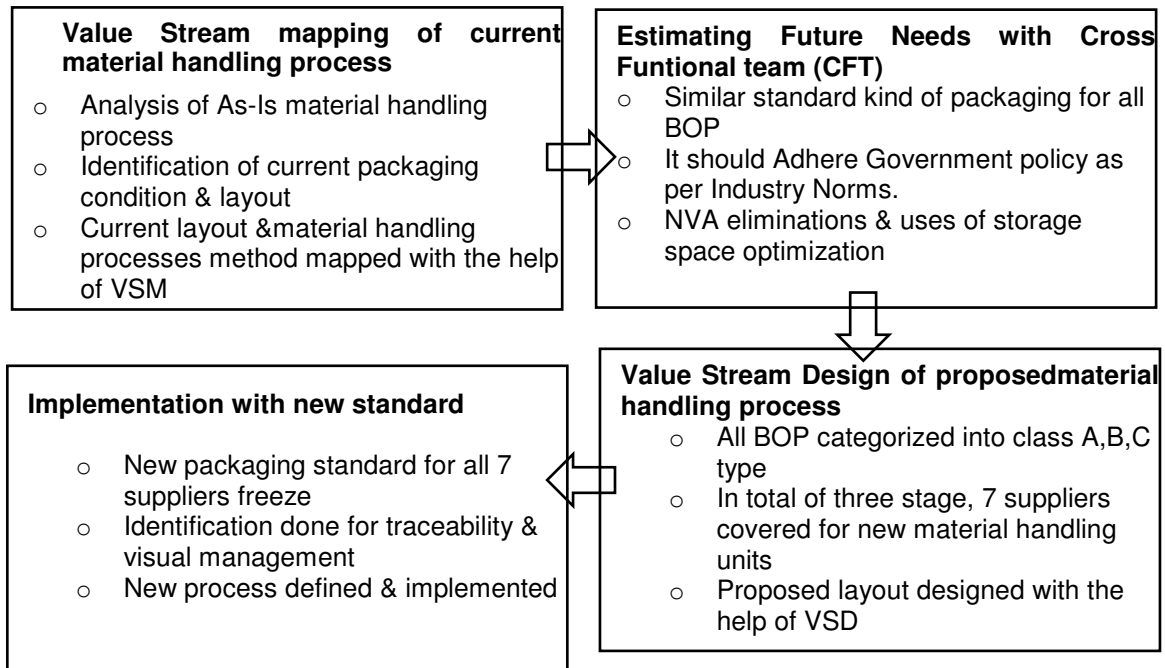


Fig. 3.2

4. CASE STUDY

In this section, a detailed case study is illustrated with the above methodology. ABC Ltd. is a leading manufacturer of industrial components and systems in India, supplying to industries such as automotive, steel etc. in the country. This study has been carried out at ABC Plant. The plant is designed for meeting increased demand of product across the country in all segments. Also this plant is associated with the reputed OEMs to meet their demand.

This study is to review & understand the difficulty of handling, storage & issue of material related to the Bought out Parts (BOP) as well as in-house parts. Also the study includes the feasibility study of production line & supplier side as well. Then after considering all of this study define proper material handling unit (MHU) standard for all these components so that nonstandard packaging can be eliminated & reduced NVA in the plant.

The study makes a number of recommendations on how the material handling process can be improved & improve visual management in raw material store. ABC Plant has probably the widest range of product families producing industrial components. The main problem for these plant maximum suppliers supplying parts in nonstandard packaging & most of the parts received in poor condition. All these components are repacked/repalletized in the Plant to store or to service it to the production line. The objective of the paper is to design standard material handling unit to ensure that material received from the supplier can be stored as it is and can also be serviced on the production lines as it is.

In current scenario ABC Plant handling more than 80 products with 3000 product variants which is the major headache for the management team for planning & fulfill all customer demand. In such a condition it is quite difficult task for store team all components in proper condition. In present condition the plant is facing major problem of poor raw material receiving condition, nonstandard packaging material used by suppliers, no proper identification done by suppliers. The major aim of paper is to define proper weight standard of material packets & define standard quantity for all components. Also aim of the paper is to define identification standard for each component & ensuring that should be feasible for line & easy for accountability.

4.1 Value Stream Mapping of Current Handling Processes

After discussion with the co-author, the following was agreed to be the scope of the paper. The paper was to investigate the processes within the plant & the research could be handle in three phase. In starting phase study of most critical suppliers for "A" class items & recommendation for these items should be prepared & at the same time focus on Implementation. In second phase "B" class item & in third phase "C" class item to be covered. With that study of current state mapping, design of future state can be done for optimization of packaging. Implementation part can be taken care after the discussion with internal plant management team as they shown their interest towards the research.

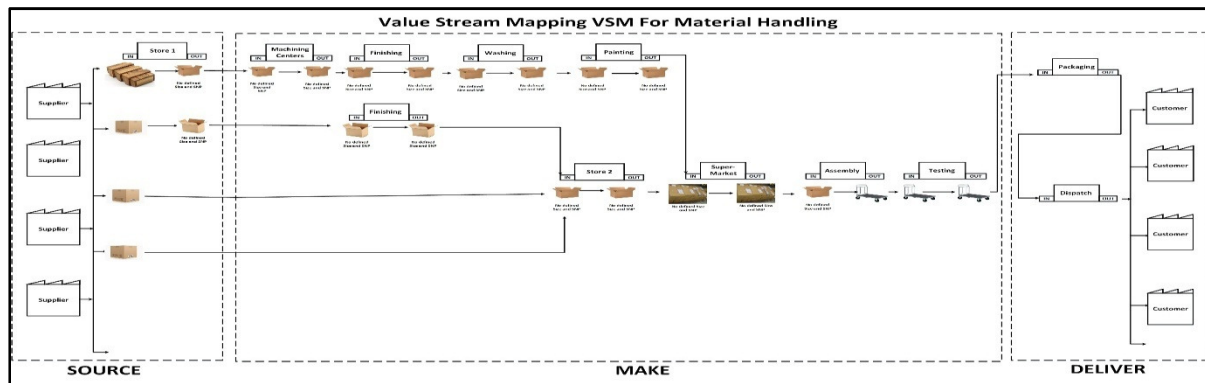


Fig. 4.1.1

PROCESS ACTIVITY MAPPING		Time (Min)	Man Power	Operation	Transport	Inspect	Store	Delay
Sl. No	PROCESS/ ACTIVITY			●	➔	■	▲	■
1	Delivery Challan (D.C.), Invoice, TC etc.	15	3	●				
2	Put Inward stamp at back side of supplier's D.C./ Invoice	1		●				
3	Make entry of inward material in "Inward Register"	2		●				
4	Send material along with D.C./ invoice to Warehouse	5	1		➔			
5	Physical unloading of material by suitable means at warehouse	60	3	●				
6	Verification of variety of items, no. of packs against that mentioned in D.C. and putting a tick mark	15		●				
7	& inspection" with date and sign on one copy of D.C. as an acknowledgement	2				■		
8	Verification of physical quantity against D.C./ Invoice	1	1	●				
9	finance; In case of any error inform finance and clarify	2		●				
10	Put a tick mark on DC/ Invoice with red / blue marker	1		●				
11	Put a tag on the material detailing the item code, quantity and date	1		●				
12	bins / pallets / packings as per requirement	5					▲	
13	Sends the D.C./ Invoice back to store personnel for GRN entry in the system	2	1		➔			
14	Verification of DC	1		●				
15	Prepare GRN and send invoice to finance as applicable	2		●				
16	Send original GRN copy to store person to mark GRN number on tag	2		●				
17	Quality dept. for incoming inspection with entry in book	2	1		➔			
18	Waiting time for Inspection	15						●
19	Incoming inspection by Quality team	5				■		
20	Ok Material sent to Stores for storage alongwith GRN & Ok material tag.	2			➔			
21	Unload the material by suitable means	60	3	●				
22	Store the material in respective location	15					▲	
23	Receive production order with picklist from planning	2		●				
24	Logical issue of material in SAP	2	1	●				
25	Physical retrieval of the material	5		●				
26	issue all the material to Production, keep loose items in different colour pallet and keep in stores and issue	5		●				
27	Deposition of material	2		●				
TOTAL TIME		232						
TOTAL NO OF OPERATORS			14					

Fig. 4.1.2

4.2 Estimating Future Needs with Cross Functional Team (CFT)

Material handling unit designing criterias are defined as below.

4.2.1 Government Policy

As per the policy of state Government of State, each of the labor working in the industry should not handle more than 18 kg in case of male & 14 kg in case of female worker. Keeping this point the box has been designed for the BOP. This will increase the efficiency of the labor & help organization to adhere standards of policy.

4.2.2 Crush Test

During designing of the material handling units clear instruction has been given to the suppliers to maintain their material handling units strength at least 15 kg so that in transit damages can be avoided & material can reach to factory in proper condition. It will also help to workforce in case of handling.

4.2.3 Strapping of MHU

All suppliers are instructed to strap the material once it is packed in material handling units to avoid shaking while moving the part from one place to another. This will help to avoid wear & tear of box during transportation from suppliers to company.

4.2.4 Accountability & Inventory Control

As plant dealing with 3000 product variants as of now, huge amount of money involved in the business. So the organization needs to focus constantly on the accountability of these parts. Keeping right qty of material in stock for respective variants will make the work easier. For that it requires lots of time & money, for making this activity easier while designing the material handling unit standard we focused on two major things called primary & secondary material handling unit standard. In primary standard we focused on the internal material handling unit size, qty, strength of the material handling unit material & ensure that should be feasible for line issue. & create the warehouse more visible. Tagging instruction has been given for both to identify each material from the outer part of the material handling unit itself.

4.2.5 Shop floor strategy

While designing the material handling units also focused on the material requirement or past demand by line & found that material required by line in the multiple of 100 every time so keeping this in mind design of material handling units & primary packing & secondary packing has been decided. It helps supervisors & workers both to store, issue

& return of material & bulky storage avoided. It also helps the line people to reduce or eliminate on the line storage.

4.2.6 5S & Visual Management

Keeping in mind of 5S implementation & makes the store more visually better the MHUs has been designed. However at initial implementation phase first 3S are given priority for implementation. Also it will help workmen to keep the material into the racks & pallets easily & ensure the complete uses of storage space of rack & pallets. It also helps to understand the store more easily & about the location of each part inside the store. Also the material handling units are designed similar size & shape makes the store more unique. It also helps SAP to feed standard material handling unit into the system which saves a lot of time for accountability & location identification.

4.2.7 Manual Material Handling (MMH)

According to the U.S. Department of Labor, handling is defined as: Seizing, holding, grasping, turning, or otherwise working with the hand or hands. Fingers are involved only to the extent that they are an extension of the hand, such as to turn a switch or to shift automobile gears. In this publication, handling means that the worker's hands move individual containers manually by lifting, lowering, filling, emptying, or carrying them.

Manual material handling tasks may expose workers to physical risk factors. If these tasks are performed repeatedly or over long periods of time, they can lead to fatigue and injury. The main risk factors, or conditions, associated with the development of injuries in manual material handling tasks include:

- Awkward postures (e.g., bending, twisting)
- Repetitive motions (e.g., frequent reaching, lifting, carrying)
- Forceful exertions (e.g., carrying or lifting heavy loads)
- Pressure points (e.g., grasping [or contact from] loads, leaning against parts or surfaces that are hard or have sharp edges)
- Static postures (e.g., maintaining fixed positions for a long time)

Repeated or continual exposure to one or more of these factors initially may lead to fatigue and discomfort. Over time, injury to the back, shoulders, hands, wrists, or other parts of the body may occur. Injuries may include damage to muscles, tendons, ligaments, nerves, and blood vessels. Injuries of this type are known as musculoskeletal disorders. In addition, poor environmental conditions, such as extreme heat, cold, noise, and poor lighting, may increase workers' chances of developing other types of problems.

4.3 Value Stream Design of Proposed Handling Processes

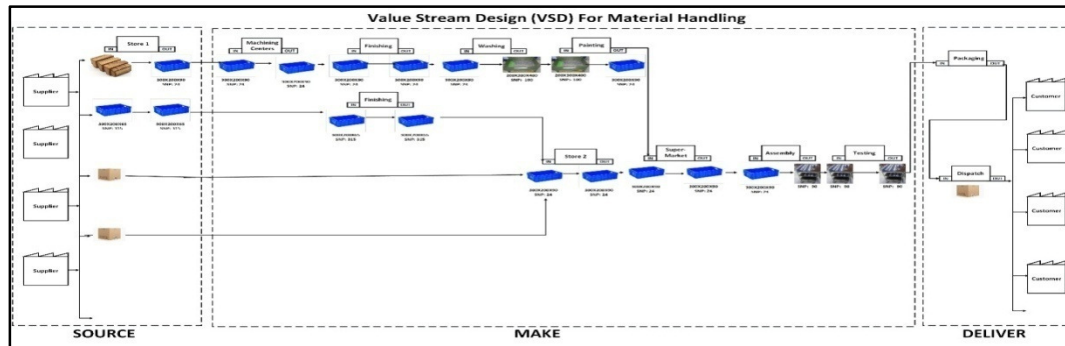


Fig. 4.3.1

4.4 Implementation with new standard & Results

The proposed designed implemented in this case organization ABC Ltd.

The following action plans were made for this work.

- Identify problems in store with respect to packaging of BOP
- Analyze problems to find out the root cause
- Redesign & find out the new material handling unit standard to improve ROP & to reduce COPQ
- Give suggestions to increase work efficiency of workers

PROCESS ACTIVITY MAPPING		Time (Min)	Man Power	Operation	Transport	Inspect	Store	Delay
Sl. No.	PROCESS/ ACTIVITY							
1	Material inward at gate along with Delivery Challan (D.C.), Invoice, TC etc.	8	1					
2	Put Inward stamp at back side of supplier's D.C./ Invoice	1						
3	Make entry of inward material in "Inward Register"	2						
4	Send material along with D.C. / invoice to Warehouse	5						
5	Physical unloading of material by suitable means at warehouse	8	1					
6	Verification of variety of items, no. of packs against that mentioned in D.C. and putting a tick mark	5						
7	Putting a stamp "Subject to counting & inspection" with date and sign on one copy of D.C. as an acknowledgement	2						
8	Verification of physical quantity against D.C. / Invoice	1						
9	finance; In case of any error inform finance and clarify	2	1					
10	Put a tick mark on DC/ Invoice with red / blue marker	1						
11	Put a tag on the material detailing the item code, quantity and date	1						
12	Store the material in proper racks / bins / pallets / packings as per requirement	5						
13	Sends the D.C. / Invoice back to store personnel for GRN entry in the system	2	1					
14	Verification of DC	1						
15	Prepare GRN and send invoice to finance as applicable	2						
16	Send original GRN copy to store person to mark GRN number on tag	2						
17	dept. for incoming inspection with entry in book.	2	1					
18	Waiting time for Inspection	15						
19	Incoming inspection by Quality team	5						
20	Ok. Material sent to Stores for storage alongwith GRN & Ok. material tag.	2						
21	Unload the material by suitable means	8	1					
22	Store the material in respective location	5						
23	Receive production order with picklist from planning	2						
24	Logical issue of material in SAP	2						
25	Physical retrieval of the material	5	1					
26	Issue all the material to Production, keep loose items in different colour pallet and keep in stores and issue when required	5						
27	Deposition of material	2						
TOTAL		101						
OPERATORS			8					
% Improvement		56%	43%					

Fig. 4.4.1

The results obtained from the calculations

- Material handling unit designed for 7 out station suppliers for different parts
- New material handling unit standard implemented at 5 key suppliers end
- Communicated to remaining suppliers & to be implement by end of next year
- Dedicated storage area created, helped to keep material in standardized way
- Visual identification done throughout in house store
- Handling & ergonomically designed work area reduced worker fatigue
- Material handling trolley designed for material movement between store & production line to reduce effort of workmen
- All unorganized storage outside store eliminated after implementation of dedicated storage area
- Cost of poor quality (COPQ) reduced & Respect of product (ROP) improved
- Visual control of store improved & part searching time reduced
- Work pressure reduced for workmen, supervisor & improve stock keeping process
- Reduce Material handling casual from 14 to 8
- Delivery time reduced & material loading/unloading time reduced in case of industrial components from 60 mins to 8 mins

5. FUTURE SCOPE AND LIMITATIONS OF STUDY

Future Scope of the research work is given below:

- Development of kanban system for efficient communication between store and production line should takes place
- Value stream mapping for material store & issue process in order to identify and eliminate the non-value adding activities & eliminate uncertain line stoppage
- Stock level to be define to maintain correct stock level & avoid excess storage
- Receiving Inspection can be done on line to avoid multiple handling of goods

Limitations of the Study:

- Continuous follow up required for implementing the correct standard of material handling unit
- May required commercial discussion with supplier & required negotiation process
- May some of suppliers demand monetary help or cost addition to implement the new material handling unit standard
- New component addition may create confusion to decide standard material handling unit for suppliers
- May supplier will not ready to implement immediately

- May create dissatisfaction at supplier end

6. CONCLUSION

As per as the deliverables of the research work is concerned, with proposed design to optimize the time by more than 56% in material handling process& help to the organization to eliminate customer complaints by 50% . Every material comes in has its standard material handling unit & all material will reach to factory in safer & better condition. So advantages of proposed material handling process solution are

- Helps to eliminate loading and unloading activity
- Reduce effort of manual material handling activity
- Effective utilization of manpower available
- Reduce man power by 43% in case of manual material handling
- Visual management becomes better
- Reduce time in material handling process

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SECTION – II

LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Six Sigma Approach for Reduction of Vehicle In-Vehicle Out (VIVO) Hours of the Outbound Logistics of a Steel Processing Industry

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Abstract: This paper explicates Six Sigma approach undertaken in a Steel Processing Industry to alleviate the Vehicle In Vehicle Out (VIVO) hours of the outbound logistics in the industry.

The research paper presents Six Sigma approach through five different phases: Define, Measure, Analyze, Improve, Control (DMAIC) in outbound logistics which has not been done significantly in this area. The application of DMAIC to the outbound logistics has given solutions to the problems incurred due to sudden rush of vehicles at a time due to customer urgency when the finished goods were not ready, material under hold due to quality check, delay in Delivery Order credit check and material under packing when the vehicle was waiting for loading. Further, the normal VIVO in outbound logistics improved from 61% to 80% thereby enhancing Sigma level from 2.676 to 4.142. Moreover Defects Per Million Opportunities (DPMO) decreased from 119703 to 4127 within one month. The paper presents a successful implementation of Six Sigma approach to reduce VIVO time and propounds for assessing progress to researchers and practitioners in the domain of Supply Chain Management in steel processing industry.

Keywords: Six Sigma, DMAIC, VIVO Hours, Outbound Logistics, DPMO, Supply Chain Management, Supply Chain.

1. INTRODUCTION

Logistics is an efficient management of the flow of products including storage in a supply chain. It is used to plan and coordinate the movement of products timely, safely and effectively. The most effective supply chains deliver products as fast and as cheaply as possible without sacrificing quality (Ballou, 1997). A manufacturing company generally has two kinds of logistics: Inbound Logistics, which brings in all raw materials, semi-finished goods, packaging materials to the industry and Outbound Logistics: which takes out all the finished goods from the company to distributors, dealers or retailers (Parwani and Jagadeesh, 2013). Regardless of the distance, each customer expects their products to be delivered quickly and flawlessly. In order to do this smart business there are various factors considered to align the pattern of movement of products in the most convenient and practical way. One such factor is VIVO time. VIVO time is the gate entry time to exit time for an inbound or outbound vehicle. High VIVO time is a cause of dissatisfaction for elite customers as transporters have to wait for long hours inside the plant and delivery to actual customers also get delayed. This is one of the challenges a steel processing industry confronts in the age of globalization. Steel processing industries are major suppliers to automobile industries. Automobile sales have been enlarging for several years and in today's

competitive scenario the automobile companies expect their suppliers to timely deliver the quality products. And VIVO time is the most important factor that determines the rating of the supplier companies like steel processing industries. The key to sustainable turnaround lies in how steel industry faces these challenges and develops combative and anticipatory process. The problem of high VIVO time was resolved by the application of Six-Sigma in outbound logistics as discussed in this paper which aims at reducing the VIVO time by greatly eliminating the negative effects of variation in the processes. It is imperative that the outbound logistics system of a company works efficiently to ensure that the goods reach destination at earliest possible time. This in return ensures meeting the demands at the destination points and leads to increased sales and in long run strengthens customer's loyalty.

The research work follows DMAIC methodology (Agrawal, Singh and Tiwary, 2017) of Six Sigma and there are various six sigma tools used in different phase of carrying out this research work, which are Supplies-Input-Process-Output-Customers (SIPOC) Chart (Mahendru and Singh, 2015), Project Charter, Process map, Capability analysis, Pareto chart, fishbone diagram, Normality Test Multi-Vari chart, Statistical process control (SPC) and Control Plan. This research work is divided into five phases (Define, Measure, Analyze, Improve and Control) which makes the research

work systematic and at the same time easy to accomplish the final goal. In Define phase the company's process was understood, the problem was identified and improvement opportunity is defined by background information to systematically support the project. In measure phase the variation in the data was measured and after narrowing down to certain reasons due to which inappropriate VIVO hours were occurring, the analysis was done in several brain storming sessions with analytical tools(Jadhav, 2013) to detect possible variations in loading of products and corresponding root causes were generated(Agrawal, Singh and Tiwary, 2017). Then in improve phase the process performance was improved by addressing root causes, discussing the alternative ways to counter the problems and accordingly action plans were proposed, henceforth controlling the improved process and future performance.

The brief detail of Six Sigma research work:

2. DEFINE PHASE

2.1 Problem Statement

In the steel Processing company where this research was carried out, vehicles (outbound – which are to be loaded with finished goods and sent out) took approximately 5-8 hours on an average from the point of entry through plant gate and exit. Such high VIVO hours were a cause of dissatisfaction for elite customers as transporters had to wait for long hours inside the plant and delivery to actual customers also got delayed. Due to such VIVO timing transporters had to keep their vehicle engaged inside the plant which was ultimately impacting their relationships too with other customers due to unavailability of vehicle.

So there was a need of reduction in average VIVO time. The goal of this research work was to reduce average VIVO time by 25 % minimum from the current level to deliver high service level to customer, enhance customer and stakeholder satisfaction.

The expected benefit from the successful implementation of Six Sigma were improved On Time In Full (OTIF)% (Szozda, Wojciechowska, 2011), increase in customer

satisfaction, improved stakeholder (transporter satisfaction) and enhanced morale of the drivers.

2.2 Process flow chart (VIVO Loading):-

As shown in figure 1, the process flow chart of outbound logistics was drawn to define the current state of workflow in outbound logistics and to study the process for improvement.

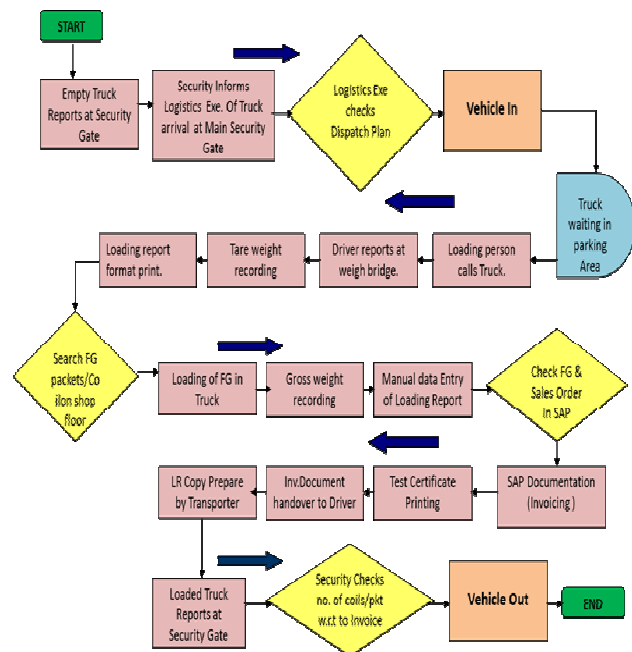


Fig. 1. Process Flow Chart of Outbound Logistics of the plant.

Process flowchart described a general mind-set to a step by step sketch for showing the process of outbound logistics from empty truck reporting at security gate to the loaded truck moving out of the security gate, but a detailed and focused diagram on the particular area of Outbound Logistics was needed. Hence SIPOC was drawn. As shown in Fig 2, SIPOC diagram along with Process flow diagram was established which summarised the whole process to define the outbound VIVO process clearly.

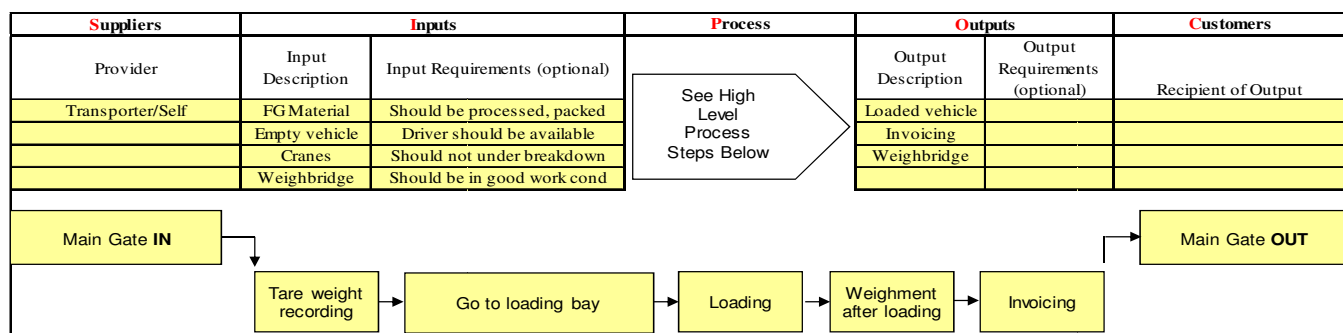


Fig. 2. SIPOC diagram with process flow diagram

The key metric which was used to evaluate the success of the research work were: DPMO (defects per million opportunities), % defects and sigma level. SIPOC Diagram with process flow diagram was established which summarised the whole

3. MEASURE PHASE

As shown in Table I, Data collection was done on each and every step of vehicle entry to Vehicle out to measure the current performance level of the outbound VIVO process.

TABLE I: Data Collection on each step

Measurement matrix	X or Y	Operation Definition	Type of data Discrete/Continuous	When will data be collected
Vehicle in Vehicle Out Time	Y	The clock time Vehicle is taken in by Security person at the Main Security Gate till the time vehicle is loaded and invoiced and leaves the Main gate	Continuous	In all shifts
Exact time at which vehicle is taken for loading (Tare weight recording)	X1	clock time between the tare weight in loading minus veh entry time recorded by security	Continuous	In all shifts
Time taken for loading	X2	Clock time between the gross weight recorded at weigh bridge minus the time at which tare weight was recorded	Continuous	In all shifts
Time taken for Invoice creation & printing	X3	Time taken for generating SAP Invoice & printing after the gross weight is taken	Continuous	In all shifts
LR Copy preparation by Transporter and security checks and outward of vehicle	X4	LR copy created by transporter minus the clock time at which the Invoice was handed over	Continuous	In all shifts

Thenormality of 6 months data collected was checked through Anderson-Darling Normality test(Anderson, 2010) to determine if data set is well-modeled by a normal distribution and to compute it for further analysis.

The outcome of the normality test is shown in Fig3, 4.

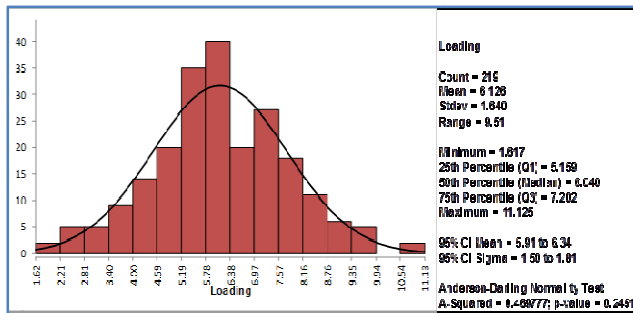


Fig. 3.: Normality Test

Process Sigma Level Calculator - Continuous Data (Assumes that data are normally distributed)			
Sample Data (user inputs):			
Mean	x-bar		5.6
Standard Deviation	s		0.34
Upper Specification Limit	USL		6
Lower Specification Limit	LSL		3
Sigma Shift (typically +1.5 for long term data)			1.5
Results:			
Expected dpm > USL			119703.4
Expected % > USL			11.97%
Expected dpm < LSL			0.0
Expected % < LSL			0.00%
Expected dpm (overall)			119703.4
Expected yield (overall) %			88.03%
Process Sigma Level			2.676

Fig. 4. Process Sigma Level

Since p value is greater than 0.5 the data is normal. Then after the further calculation was carried out on the data. Sigma Level was calculated before implementing DMAIC model and the value was 2.676 and DPMO (Defect per Million Opportunity) was 119703.4

4. ANALYSIS PHASE

This phase is the most important to find the causes of mostly changing the process by identifying the bottlenecks of the process and henceforth digging out the sub causes of the problems(Patil et al, 2015).

4.1 Analysis on Sample data

Pareto Analysis was done on the 6 months data (Fig 6). It

was observed that out of 17 reasons responsible for long vivo hours, 5 of the reasons contributed to 80% of the long VIVO hours.

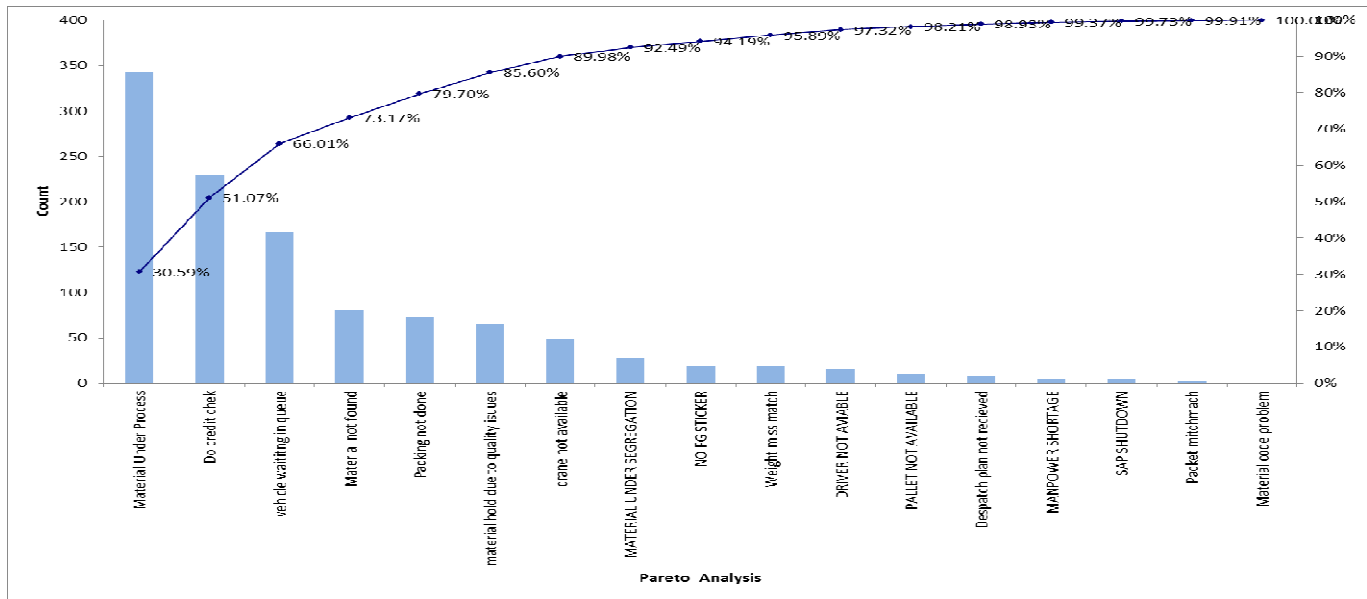


Fig. 5. Pareto Chart of Past data

The major reasons which caused high VIVO time were Material under process, Material under packing or packing not done and Deliver order credit check delay.

After selecting the bottlenecks with higher frequency that led to high VIVO time, rigorous brainstorming in the why-why sessions cause and effects diagram for all the bottlenecks were highlighted, all of these factors are summarized in the fishbone diagram in Fig. 9, 10, 11. The parameters considered were: Man, Method, Material, Machine, Customer and Transporter. Moreover the sub causes to the causes generated were also found.

- CAUSE AND EFFECT DIAGRAM OF material Under Process & DO credit Check was drawn (SEE fig 9, 10)

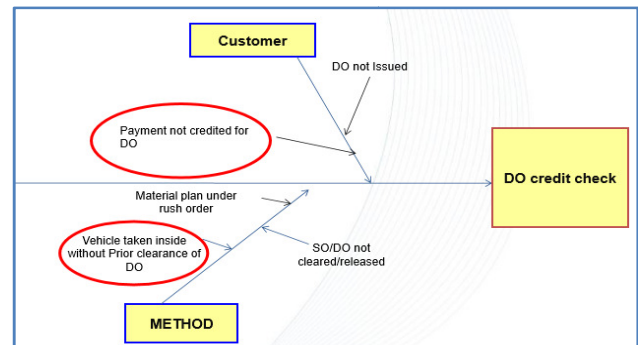


Fig. 7. Cause and effect diagram

- CAUSE AND EFFECT DIAGRAM OF material Under Packing (see fig 11)

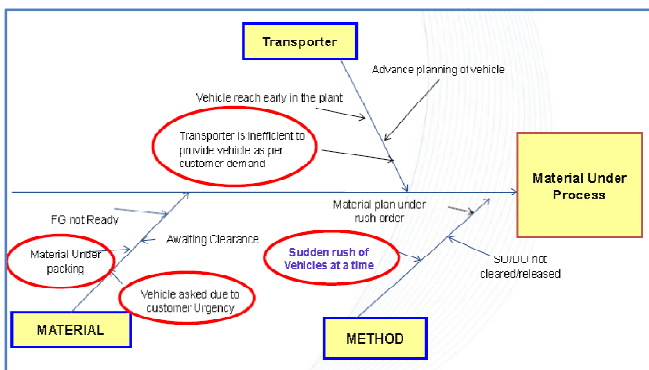


Fig. 6. Cause and effect diagram.

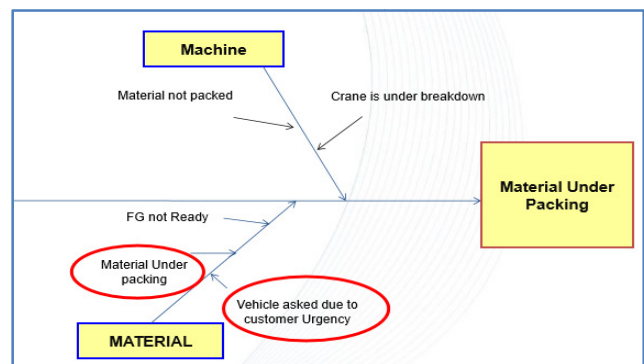


Fig. 8. Cause and effect diagram.

The major sub causes which led to the high VIVO time is marked red in the fish bone diagram.

The team had a detailed discussion in this regard with the engineers, the operators and supervisors in charge. Based on this discussion, an action plan was prepared with details of data on each cause and the type of validation required.

5. IMPROVE PHASE

This phase statistically reviewed the variations in the process and determined what factors significantly contribute to the output (Patil et al, 2015). The main goal of this Improve phase was to develop optimal solutions of the problems henceforth the Action Plan was made ready to reach the goal as shown in Table II.

TABLE II: Action Plan for improvement of outbound logistics.

SN	Major Reasons for High VIVO hours	Root cause	Responsibility	ACTION PLAN
1	Credit check/ DO not released for Customers	Due to same day planning of vehicle DO's are not released as per dispatch plan	Logistics Team	1 day advanced despatch plan will be done, DO will be released same day and vehicle will be placed second day.
2	Material under process	Due to Vehicle Placed prior to FG ready vehicle waiting time increased	Logistics Team	Despatch plan will be done purely on FG availability, vehicle will be placed after FG
3	Vehicle waiting in queue	Due to Multiple loading points vehicle wait in queue parking area	Despatch Team	FIFO system will be followed and from now onwards if FG will be ready in advance vehicle waiting time will be reduced
4	Packing not done	Due to Material showing FG in system & Physically materials packaging is pending.	Despatch team, Packaging contractor & Production	to be discussed with Production and Packaging contractor for packaging lead time finalization

- **Material Under Process:** Earlier higher outbound vehicles delayed due to Material under process. Then the action taken was that the Vehicle planning will be done after material will be ready as Finished good.
- **Loading point busy** –Earlier vehicle used to wait in a queue but then the action taken was that the FIFO system would be followed.
- Earlier there used to be delay due to Delivery Order credit check. But then the action taken was: Vehicle will not be allowed to enter In the plant without advance delivery order or credit order.
- **Material NOT FOUND** was another reason for higher VIVO hours so the action taken was that the Auto Delivery system was installed. It resulted in reduction of Invoicing Delay and Material not found delay.
- Cold Rolled and Hot Rolled Finished Goods packets were arranged Material Thickness wise. This helped to reduce the Material Searching time.
- There were several cases of Packing not done so the action taken was that a 2.5 Mt small crane was installed in the CR plant to improve the Packaging speed for Narrow coils.

After the attainment of these improvement actions, Defects per million and sigma level were calculated. The process

showed the sigma level rise of 2.4 in Cold Rolled plant's outbound logistics and 1.46 sigma level rise in Hot Rolled plant's outbound logistics.

6. CONTROL PHASE

One month after the containment action % defect, DPMO and Sigma Level of the complete VIVO process were calculated to measure the overall improvement of the process (Agrawal, Singh and Tiwary, 2017) (Table III).

TABLE III: Sigma Level comparison before and after.

Metric	Before	After
% Defect	11.97%	.41%
DPMO	119703	4127
Sigma level	2.676	4.142

The major problems for the inappropriate VIVO hours were analyzed and corrective actions were taken. The correct VIVO time improved from 61% to 80%. Sigma level rose from 2.676 to 4.142. Such rise in sigma level is quite beneficial for the company.

Process Sigma level calculation of the continuous data is shown in figure 12.

Before			After		
Process Sigma Level Calculator - Continuous Data (Assumes that data are normally distributed)			Process Sigma Level Calculator - Continuous Data (Assumes that data are normally distributed)		
Sample Data (user inputs):			Sample Data (user inputs):		
Mean	x-bar	5.6	Mean	x-bar	4.3
Standard Deviation	s	0.34	Standard Deviation	s	0.265
Upper Specification Limit	USL	6	Upper Specification Limit	USL	5
Lower Specification Limit	LSL	3	Lower Specification Limit	LSL	2
Sigma Shift (typically +1.5 for long term data)		1.5	Sigma Shift (typically +1.5 for long term data)		1.5
Results:			Results:		
Expected dpm > USL		119703.4	Expected dpm > USL		4126.9
Expected % > USL		11.97%	Expected % > USL		0.41%
Expected dpm < LSL		0.0	Expected dpm < LSL		0.0
Expected % < LSL		0.00%	Expected % < LSL		0.00%
Expected dpm (overall)		119703.4	Expected dpm (overall)		4126.9
Expected yield (overall) %		88.03%	Expected yield (overall) %		99.59%
Process Sigma Level		2.676	Process Sigma Level		4.142

Fig. 9. VIVO Process Sigma level calculation

7. CONCLUSION

The variation reduction and reduction of defects are critical to the logistician by managing inventory, customer's trust and smooth movement of goods timely. This research work proposes the 'VIVO Hours Analysis Of Outbound Logistics' in a steel processing industry. A detailed process map was drawn and the bottlenecks in the smooth flow of the process were identified. A pareto chart was drawn to find out which were the major reasons leading to inappropriate VIVO hours. They were identified as material under process, material under packing or packing not done, deliver order credit check delay and loading point busy. Then after fishbone diagram(Rumana and Desai, 2014) was drawn to find the causes for these effects and subcauses were identified. Then further analysis of each potential root causes were conducted using a lot of brainstorming sessions. For each cause, emendation was provided. The action plan was designed and improvements were implemented. The potential benefits from the chosen solutions were evident from the very next day. (Mijajlevski, 2013)

The correctedVIVO rose from 61% to 80% and Sigma level enhanced from 2.676 to 4.142 in one month. Such rise in sigma level is lucrative for the company.

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Conceptual Framework to Prioritize Performance Measures for Hospital Supply Chain Management

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Abstract: The ever increasing requirement of providing better services in hospitals at reasonable cost, in least possible time has made to proactively think towards identify and prioritise the areas of concern, which can integrate all business operations of hospital. To accomplish this, supply chain management (SCM) has role to play in reducing cost, time and improving the performance in hospital operations and thereby enabling the hospital supply chain for continual improvement. In order to address the issue of performance measurement of hospital supply chain, one must consider hospital supply chain efficiency. This paper reviews briefly the existing literature on hospital supply chain performance measurement. & identify the challenges of hospital supply chain management and potential performance measure to evaluate the performance of hospital supply chain. Identification and prioritization needs proper framework to categories the constructs. Hence, the objective of the paper is to present conceptual framework considering the supply chain efficiency parameters with various attributes and hospital supply chain components (Medical Treatment Operation & Supporting/ Allied Operations). The framework is proposed to prioritize various performance metrics identified from literature review.

Keywords: Supply ChainManagement, Hospital Supply Chain, Healthcare supply chain, Performance Measures, Analytical Hierarchy Process

1. INTRODUCTION

The philosophy of supply chain management has been adopted to supervise various operation/ activities over longer period of time. In order to be assured of successful supply chain management adoption, performance measurement is very important. Performance measurement is a tool to monitor the efficiency and effectiveness of operation being carried out [Kumar et al., 2005; Neely et al., 1996]. Supply chain performance measurement must consider whole supply chain perspective. It can be done by considering business operation carried out in particular supply chain. Performance measurement of supply chain must be done to enhance the effectiveness and efficiency of supply chain as a whole [Beamon, 1999]. Few work present the development of performance measurement framework in hospital, whereas they lack in considering hospital supply chain aspect[Berenson et al., 2013; Bititci et al., 2010]. While other studies focuses on the measurement and improvement of particular business operation in hospital supply chain [da Encarnação et al., 2009; Elg et al., 2013]. There are very limited number of studies which explored the hospital supply chain performance measurement as a whole [Lorden et al., 2008; Purbey et al., 2007]. This paper proposes a conceptual hierarchical framework for prioritizing performance measures. Proposed framework considers the supply chain efficiency dimensions as criteria

and hospital supply chain operation as alternatives to monitor the performance.

The rest of the paper is presented in 6 sections; section 2 covers an overview of work done on hospital supply chain performance measurement, section 3 elaborates the various operations/ activities/ processes of hospital supply chain, section 4 presents performance measurement criteria for hospital supply chain and associated sub-criteria. Proposed conceptual framework and prioritization of performance measures will be presented in section 5, section 6 concludes the study followed by section 7 of reference.

2. OBJECTIVE OF PROPOSED CONCEPTUAL STUDY

Hospital supply chain is constantly going through challenges and opportunities resulting due to ever dynamic operation conditions which consist of expectations of service quality of healthcare at affordable cost. Concurrent improvement in quality and efficiency leads to make customer demands more expensive. Measuring the performance can enable the healthcare professionals to assess the improvement in activities towards attainment of strategic goals and objective of the hospital. Adoption of appropriate performance measures/ metrics plays most important role in highlighting the efficiency of healthcare supply chain performance measurement. The selection of these performance measures widely considers the benefits of

hospitals, clinicians and customers(patients). These will help in raising the service value of healthcare supply chain management/. During literature review related to supply chain performance measurement of hospital supply chain, we came across various measures such as healthcare services, communication, patient safety, waiting times, and integration, which affects the supply chain management. Whereas, cost and time are the most important criteria of today's hospital supply chain.

Along with this, reliability of utilized healthcare services and productivity of medical treatment processes is also an vital criteria for today's hospital supply chain. Together, if we consider the aspects of cost, time, reliability and productivity of supply chain, they becomes the construct of supply chain efficiency. Therefore, improving overall supply chain efficiency with high level of service quality is major context for enhancing hospital supply chain performance. Besides this, in order to recognize the processes of hospital supply chain for successful management of supply chain, therefore must look at both operation of hospital supply chain i.e medical treatment operation and supporting/ allied operations. The sole objective of this study is to provide and an brief overview on performance measurement of hospital supply chain. More precisely, the purpose of this study is to;

- i. To identify the performance measures for constructs under supply chain efficiency for hospital supply chain.
- ii. To proposed a conceptual hierarchial performance measurement framework for hospital supply chain considering supply chain efficiency drivers and hospital supply chain operations.

3. OVERVIEW OF LITERATURE ON SUPPLY CHAIN PERFORMANCE MEASUREMENT IN HOSPITALS

3.1 Brief Overview of Performance Measurement System

Performance measurement facilitates guidance, and improvement action in various conditions depending on the contextual utility and application (Elg et al, 2013). Further, the concept of performance measurement system is predominantly applied in public reporting, provider incentive programs and also in quality improvement programs (Berenson et al, 2013). Performance measurement system are conceptualized in various ways such as "organizational performance assessment system", outcome based management system" etc. Several definition were introduced in the literature by various authors exhibiting its application areas in an attempt to resolve this complexity of performance measurement system.

3.2 Performance Measurement System for Healthcare Supply chain Management

Globally, there is an intense complexities in healthcare systems. Owing to which, healthcare service providers are challenged to provide efficient services at affordable cost. Hence, healthcare performance measurement becomes very important, specially considering the overall activities of the hospital supply chain management. It becomes important to recognize the supply chain management components in hospital, which can be considered for continuous improvement leading to improved service quality and safety. Elements of supply chain management for hospital consist of medical treatment unit, supporting units and hospital storage treated as internal supply chain(Supeekit et al, 2015), whereas, externally chain includes vendors, manufacturers and distributors etc. The prime concentration of healthcare supply chain management relies on its performance assessment. The ultimate aspect for healthcare supply chain is safety and satisfaction of the patient.

Healthcare supply chain is very complex yet unexplored. There are multiple reasons for healthcare supply chain management to be immature which can be less management involvement, redundancy in clinical processes, etc. Also, cost has major impact in healthcare supply chain(Kumar et al, 2008). Constraint of time plays vital role while considering the safety of the patient. It has been evident that, there is very less studies explored the potential of hospital supply chain an internal chain. Hence, paper projected to consider the hospital supply chain with an approach of proposing a framework for performance measurement of supply chain. Here, we would be considering the subsets of internal supply chain such as medical treatment operation and supporting/allied operations. Success of any supply chain lies in improving its efficiency(Supeekit et al, 2015). Therefore, we suggest to consider the construct of supply chain efficiency with hospital supply chain operation to design a framework.

4. HOSPITAL SUPPLY CHAIN OPERATION

Hospital supply chain in this study is shown in figure 1. It is one of the most complex supply chains. End user of hospital supply chain is patients who seek diagnosis and pursue the treatment (Dobrzykowski et al, 2009). For achieving the satisfaction of patients (customers), both medical treatment (services from medical professionals) and supporting operations (pharmaceutical and medical supplies) are equally important (Parnaby et al 2009 & Singh, 2008). In order to improve the efficiency of hospital supply chain performance for successful management of the supply chain, it is important to explore various activities under major hospital supply chain operation i.e. medical care and supporting operations, which are as given below;

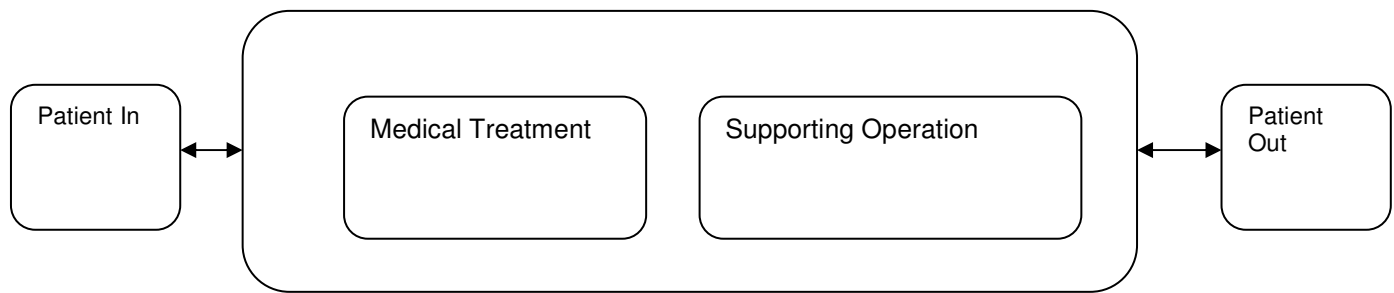


Fig. 1. Hospital Supply chain

A. Medical Treatment Operations

Medical treatment operations facilitate medical overhaul to patients (customers). Main resources for this operation are doctors, nurses; whereas medical tools and equipment are integral part while treating to patients. There are various places where medical treatments are done such as Surgery, Neurology and Pediatrics etc. Medical treatment activities as cited in literature (Bhattacharjee et al, 2014 & Kujala, 2006 & Rahimnia et al, 2010) are as follows;

- i) **Admittance:** - Most initial activity, various stages are there is this activity for patients to be cared and treated. Stages such as registration, triage, and inpatient admission.
- ii) **Patient Examination:** - In order to be treated properly and to get cured as early as possible, patient's examination is done by nurses and doctors.
- iii) **Treatment Delivery:** - Post examination, mode and pattern of treatment is decided. Treatment can be of short span/ long term depending on the nature of patient's disease.
- iv) **Discharge/Transfer:** -Preferably the last stage at any hospital. This is done in either cases, when patient is treated and cured or when patient's criticality is not in reach of particular hospital expertise.

B. Supporting/ Allied Operations

Supporting operation adds value to medical treatment processes. In order to examine, treat and cure patient, clinical materials such as pharmaceutical, medical supplies, and medical equipment are required. These processes normally occur into two major units: medical supporting units (Singh 2008, Swinehart et al, 2005 & Narayana et al, 2014 & Mustaffa et al, 2009) such as radiology, laboratory and pharmacy; and non-medical supporting units (Kumar et al 2005, 2008 & Singh 2008) such as porting service for patient, supply & demand management, and sterilized services. The supporting processes involve the following processes.

- i) **Supply & Demand Management:** - This includes procurement of medical materials from various suppliers or supporting units when needed.
- ii) **Synthesis:** - This includes the preparation of medical treatment materials for clinical operations.
- iii) **Movement:** - This includes transfer of materials or patient to the point of care or where the materials or patients are required to be treated.
- iv) **Stock & Capacity Management:** - This include the processes to ensure the availability of medical materials while keeping the cost lowest possible and also it ensures the resource management in the hospital to avoid wait/ delays.

5. HOSPITAL SUPPLY CHAIN PERFORMANCE

Performance measurement is a process which provides strategic decision making for improvements in firm/ organization. In order to observe improvement in a supply chain, the initiatives for performance measurement must be supply chain centric so as to enhance supply chain efficiency (Beamon 1999 & Cai 2009 & Gunasekaran et al 2004, 2007). Hence, hospital supply chain performance measurement must ensure the involvement of supply chain efficiency in medical treatment and supporting operation. Studies revealed that, (Barnabè 2011 & Battini 2009) patient safety primarily be the most important concern to ensure best possible service to patient. In order to ensure patient safety, the supply chain performance measurement system for the hospital supply chain should consider the supply chain efficiency constructs as the criteria with various sub-criteria contribution to overall supply chain performance for hospital. Furthermore, the performance measurement system must possess a unambiguous justification of criteria and a relationship model between criteria, sub-criteria and alternative on which performance of supply chain is to be evaluated (Cai 2009 & Berrah et al 2007). This section would explore the hospital supply chain performance criteria including supply chain efficiency criteria.

5.1 Supply Chain Efficiency: -

Supply chain efficiency takes into consideration of multiple performance criteria linked to supply chain operations with integration of supply chain partners (Aronovich 2010 & Pettersson 2008). The most important criteria which are considered while thinking of supply chain efficiency include cost & time (Goedhals 2010 & Pettersson 2008), whereas with respect to supply chain context reliability received lot of attention. In addition, so as to measure the efficient use of resources, productivity has also gained lot of importance (Pettersson 2008). Therefore, supply chain efficiency with four dimensions for this study is as follows;

- i. Cost- Managing Cost effectively and efficiently
- ii. Time- Managing Time of all operations with high responsiveness
- iii. Reliability- Ensuring the accuracy of the treatment processes and its sustainability.
- iv. Productivity- Ensuring optimum utilization of resources available to carry out medical treatment processes.

6. CONCEPTUAL FRAMEWORK FOR HOSPITAL SUPPLY CHAIN PERFORMANCE MEASUREMENT

This section presents the conceptual framework for measuring hospital supply chain performance measurement. As discusses earlier, framework is conceptual and presented based on brief overview of available literature pertaining to healthcare supply chain management, more precisely

hospital supply chain. The need of the hospital supply chain management is studied. Four constructs for supply chain efficiency is considered, which are; cost, time, reliability and productivity as discusses earlier. In order, to gauge the performance more accurately, various performance measures were identified from literature and categorized as per their characteristics under these constructs of supply chain efficiency. The various performance measures are as shown in table 1. Performance measures identified from literature review list in the table probably may not be all are equally relevant and critical to assess the hospital supply chain performance. Hence, the purpose of this study is to present a framework to prioritize them and rank as per their level of contribution towards supply chain performance in hospital supply chain.

The framework also consist of areas where these criteria and sub-criteria would affect, and they are the compoenet of hospital supply chain management (Medical Treatment Operation & Supporting/ Allied Operation).

The proposed framework is composed of following elements;

Overall Goal: - Hospital Supply Chain Performance

Criteria: - Medical Treatment Operations, Supporting/ Allied Opertaion (Compoenents of Hospital Supply Chain Management)

Sub-criteria: - Total 50 performance measures grouped under components and categorized based on their nature.

Alternatives: - Supply Chain Efficiency Constructs (Cost, Time, Reliability, Productivity & Safety)

TABLE 1: Performance Measures for components of hospital supply chain categorized under four criteria

Sr. No.	Performance Criteria	Components of Hospital Supply Chain Management	
		Medical Treatment Operation(22)	Supporting/ Allied Operation(28)
1	Cost	i. Cost of Inspection ii. Cost of Capital resources iii. Cost of Care iv. Operating Cost	i. Cost to issue orders ii. Total cost of supplies iii. Inventory days of supply iv. Value of buffer stock v. Revenue per Physician
2	Time	i. Time to Admit ii. Patient waiting time iii. Response Time to Unplanned Issue iv. Time to discharge v. Patient Turnaround time	i. Sourcing Response Time ii. Order Lead time iii. Order processing Time iv. Order fulfillment cycle time v. Production/ Preparation Time vi. Transportation Time vii. Cycle Time for
3	Reliability	i. Accessibility ii. Accuracy of Results iii. Accuracy of Medical Treatment iv. Accuracy of Discharge Process	i. Lead Time Variability ii. Fill Rate iii. Percentage of Rush Orders iv. Accuracy of Orders

Sr. No.	Performance Criteria	Components of Hospital Supply Chain Management	
		Medical Treatment Operation(22)	Supporting/ Allied Operation(28)
			v. Stock out at point of Use vi. Stock Accuracy vii. Pick & Pack Accuracy viii. On Time Delivery ix. Response Time to Urgent Request
4	Productivity	i. Availability of Tool ii. Productivity of Testing Lab iii. Productivity of Doctors iv. Productivity of Support Staff (Nurses) v. Resource Utilization vi. Bed Turnover	i. Inventory Tunover ii. Availability of Tools/ equipments iii. Staff Productivity iv. Availability of Porters
5	Safety	i. Technical Quality of Care ii. Communication/Information iii. Caring/Compassion	i. Authentication of Medical Suppliers ii. Handling of Clinical Material iii. Availability of Phamaceutical materials.

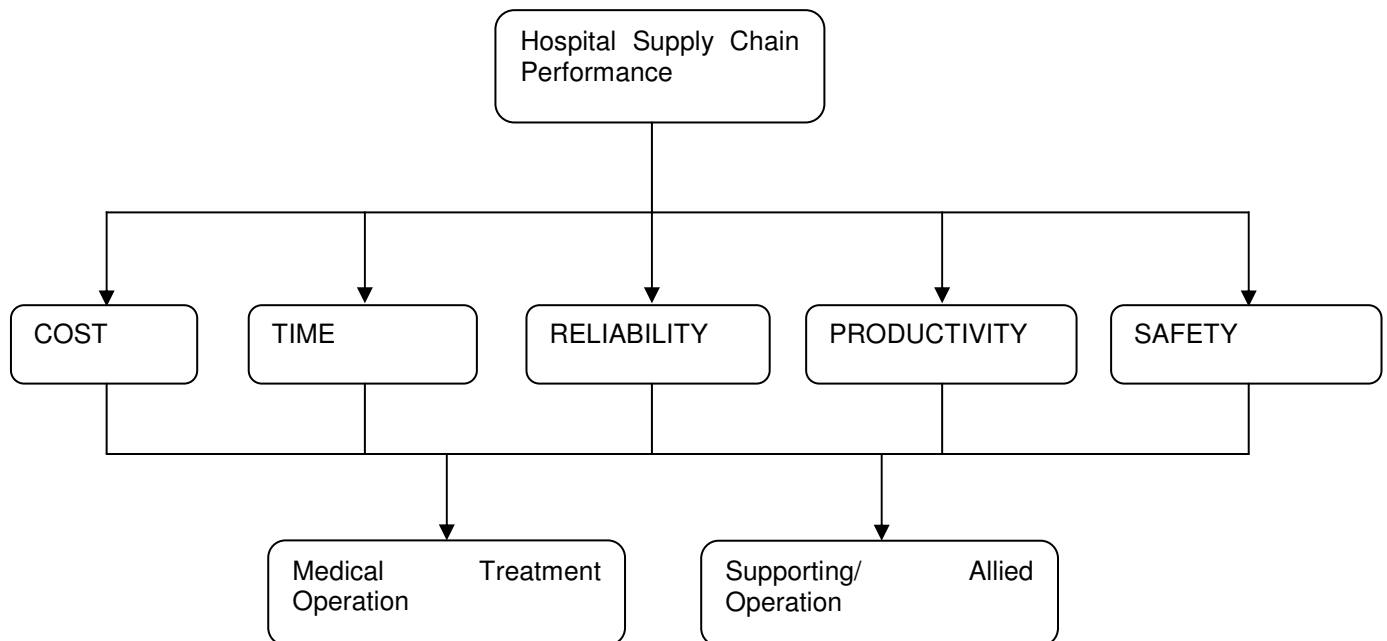


Fig. 2. Hierarchical Representation of the Framework for assessing hospital supply chain performance

7. CONCLUSION

The ultimate objective of the the study identify and prioritise critical performance measures used to assess the performance of hospital supply chain management In order, to undertake this study, brief overview of literature is done and it is evident from it, that, very scare studies are being conducted in the field of supply chain performance mearuement in the healthcare sector of india specially for hospital supply chain. Study identified that there are two parts of healthcare supply chain management, internal chain (hospital supply chain) and external chain (consist of vendors, manufactures and distributors of medical supply

supplies(pharmaceuticals and devices)). Focus of this study is concentrated on hospital supply chain management. A framework is suggested comprising of goal as overall supply chain performance, with criteria supply chain efficiency constructs i.e. Cost, Time, Reliability, Productivity & Safety with almost 50 sub-criteria or performance measures categorized under them collectively. Whereas these performance constructs and sub-criteria will be prioritised on components of hospital supply chain management i.e., Medical Treatment Operation and Supporting/ Allied Operations. The Paper presented here, proposes conceptual framework for assessing hospital supply chain performance. However, the study will follow

with prioritization and ranking of critical performance measures for hospital supply chain.

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Analyze the Enablers of Green Supply Chain Management Implementation: A Comprehensive Survey

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Abstract: The aim of this research is to study the various green supply chain management enablers (GSCMEs) and build awareness about these GSCMEs. The nationwide survey of Indian automobile organizations has been conducted to check the status of GSCMEs for successful GSCM implementation. The result shows that top management commitment and support, supplier commitment, environmental policy, strategic planning and GSCM methodology are five most important GSCMEs. The outcomes of this study have provided substantial and innovative information by signifying several criteria and a simple, efficient method through which decision makers can improve their capability to analyze the GSCMEs for successful GSCM implementation. In addition, the ranking tactics of GSCM implementation show the respondent's observations about the significance of them and helped organizations to identify their strengths to move towards continuous improvement.

Keywords: GSCM, enabler, survey

1. INTRODUCTION

The environmental concerns have prompted people from all domains of the society to take a more energetic stand for the advancement and execution of practices that can help businesses reduce their negative impact on the environment [Sarmiento and Thomas, 2010]. Organizational requirement helps in highlighting the relationship among sustainability and performance and focuses on assessing the economic, environmental and social impacts on their activities [Subramanian, and Gunasekaran, 2015]. As customers are becoming more environmentally conscious and governments are making stricter environmental regulations, the organizations need to reduce the environmental impact of their manufacturing activities [Mathiyazhagan et al., 2013]. Environmental management is an important issue in supply chain management (SCM) [Govindan et al., 2014]. For the success of environmental programs, the whole SC should go greener by implementing green supply chain management (GSCM). GSCM is the process of integrating environmental concerns into business accomplishments [Liou et al., 2016]. GSCM maximizes the global environmental profit by implementing a life cycle tactic through manufacturing, material selection, product design, and sales and recovery, and hence, supports the organization's to understand its sustainable growth and development [Shi et al., 2012]. GSCM promotes efficiency and synergy among business partners and their lead corporations [Madaan and Mangla, 2015]. The concept of GSCM is not new but there is no clear and perfect policy for GSCM implementation in the organizations. The GSCM

implementation requires identification of GSCM enablers (GSCMEs).

The aim of this research is to study the various GSCMEs and build awareness about these GSCMEs. The nationwide survey of Indian automobile organizations has been conducted to check the status of GSCMEs for successful GSCM implementation. Hence, a study of the GSCMEs of these surveyed organizations might offer a reasonable valuation for GSCM implementation for Indian automobile organizations. From literature review and experts discussion total 35 GSCMEs were selected for the analysis (see Table IV). This study is organized in four sections including introduction. Section II provides literature review about GSCMEs. Section III shows the methodology of survey and its analysis. Last section IV deals conclusion, limitations and future scope of the present study.

2. LITERATURE REVIEW

Many authors have researched and written directly on the GSCMEs. Most of the studies were emphasized on reduction, remanufacturing, recycling, product design, process plan, manufacturing practices, procurement, and some mixing of items across the managerial levels [Sarkis et al., 2011]. [Wang et al., 2016] develops a conceptual model with four hypotheses to propose moderation and mediation effects of customer relational governance (CRG) on the relationships between two GSCM practices (green innovation and green purchasing) and environmental/economic performance. Luthra et al., 2016 anticipated the overall organizational performance

outcomes by examining the impacts of critical success factors to implement GSCM towards sustainability by implementing green practices in Indian automobile industry. [Teixeira, 2015] analyzed the relationship between GSCM practices (green purchasing and collaboration with customers) and green training by presenting the empirical evidence from Brazilian firm. [Mohanty et al., 2012] presented an empirical study of GSCM practices in the Micro, small and medium enterprises (MSMEs) in India and revealed that Indian MSMEs face significant pressures from external stakeholders to adopt GSCM practices. [Muduli et al., 2013] identified twelve behavioral factors, which explore the various behavioral factors affecting GSCM practices, their interactions and help to attain green-enabled needs. [Diabat et al., 2013] focuses on ranking for GSCM practices and performances between organizations conducted in an automotive organization of a developing country. The results enable automobile manufacturing organizations to appraise their own strengths and weaknesses in implementing these practices.

[Zhu, 2012] empirically tested the theoretical relationships on the GSCM implementation. This study provides practical implications for manufacturers to identify ways for improving environmental and operational performance, as well as, economic benefits through proper design of GSCM practices. [Azevedo et al., 2011] examined the relationships among green practices of SCM and SC performance. The conceptual model provides evidence as to which green practices have a positive effect on quality, customer satisfaction and efficiency. [Holt, and A.Ghobadian, 2009] investigated the level and nature of greening the SC in the UK manufacturing sector. It also explored the driving forces behind environmental behavior, the specific management practices and the relationships among them. [Zhu and Sarkis, 2007] studied the moderating effect of institutional pressures on GSCM implementation exposed that organizations facing higher regulatory pressures tend to implement GSCM practices. [Lee, 2008] acknowledged the main drivers for organizations to contribute to the GSCM implementation as government involvement, buyer influence and GSCM willingness. [Kainuma, and Tawara, 2006] considered the extent of lean and GSCM practices. [Sheu et al., 2005] obtained seven critical factors in their research into environmental management namely total involvement of employees, green products/process design, top management commitment, training, measurement, information management and supplier management. [Wee, 2005] offered a combined

logistics operational model to manage the cross-functional product logistics flows and used-product reverse logistics flows in a given GSCM. The outcome of the proposed integrated logistics operational model helps to improve the chain-based aggregate net profits and the relative existing operational performance of the SC.

3. METHODOLOGY

A. Questionnaire survey

Instrument development

A structured questionnaire was framed to collect responses on a five-point Likert scale. On the scale, 1 stands for strongly disagree and 5 for strongly agree. The questionnaire had two sections and was designed to collect detailed information about-

- the profile of the respondents, organizations, objectives of GSCM [07 questions];
- GSCM enablers (GSCMEs) [01 Question];

Before sending the questionnaire to the organizations, a pilot study was carried. The ideas behind carrying out the pilot study were to obtain fruitful feedback from executives working in the area of GSCM, to add questions, if any, missing from the questionnaire, to delete any irrelevant questions, and to refine/rephrase the language of the existing questions to bring more clarity to the questionnaire. A total of six executives were personally contacted. Accordingly the questionnaire was modified and a final questionnaire was developed. It was then mailed to different organizations. Those executives suggested developing the subgroups among the identified GSCMEs for better understanding of the questionnaires.

Around 550 mails were sends to industries located in deferent part of the country. The total responses obtain from both online and offline are 131 which represent the response rate of 23.8%, which is satisfactory for such type of survey.

Sample characteristics of the respondents and organizations

Table I andII gives the demographic profile of the respondents (job title, job function, and years worked at the organization) and organizations participated (the primary production system, industry, employment size, profit etc.) in survey respectively.

TABLE I: Demographic Profile of Respondents (IN %)

Participants position level	Senior	Middle	Junior	
Managerial Level	12.9	47.3	39.7	

Educational qualification	Diploma	Bachelor's degree	Master's degree	Doctoral
	16.8	64.9	18.3	0
Experience(in years)	< 5 yrs	5 to 10 yrs	11 to 15 yrs	> 15 yrs
	34.4	35.9	16.8	13
Age	Below 30	30-39	40-49	Over 50
	39.7	35.9	16.8	7.6

TABLE II: Demographic Profile of Organizations (IN %)

Sector	Public	Private	Government	Others	
	6.8	85.5	3.8	3.8	
Size	Large Scale	Medium scale	Small scale		
	58	32.1	9.9		
Number of employees	<100	101-500	501-1000	Over 1000	
	5.3	28.2	24.4	42	
Annual sales turnover	<5 Cr.	5-50 Cr.	51-100 Cr.	101-500 Cr.	Over 500 Cr.
	9.9	15.3	14.5	26	34.4

B. Annual sales turnover and trends in profit of the organizations

TABLE III gives the trends observed in the annual sales turnover and profits of these organizations during the last three years.

TABLE III: Trend in Annual Sales Turnover and Profits for the Last 3 Years (IN %)

	Increased up to 10%	Increased above 10 %	Constant	Decreased
Annual sales turnover	37.4	48.9	6.9	6.9
Profit/loss	33.6	35.9	26	4.6

C. Results of survey analysis

Reliability analysis of the questionnaires

The values of alphas (α) have been found to be more than 0.5 with an average of 0.92. It implies that there is a high degree of internal consistency in the responses to the questionnaire [Rungasamy et al., 2002; Nunnally, 1978; Nunnally and Bernstein, 1994].

Descriptive statistics of GSCMEs

The relevant descriptive statistics are shown in Table IV. Also the priority weight of 35enablers is calculated by dividing each GSCME by the sum of its columns (Table IV). However the mean values 35 GSCMEs were obtained and analysis has been done.

TABLE IV: Descriptive Statistics

Influencing Factors	Mean	SD	Rank
Top management commitment and support	4.32	0.77	1
Supplier commitment	4.15	0.94	2
Environmental policy	4.09	0.85	3

Influencing Factors	Mean	SD	Rank
Strategic planning	4.02	0.75	4
GSCM Methodology	3.96	0.86	5
Organizational structure	3.95	0.76	6
Willingness towards investment	3.92	0.82	7
Employee empowerment and motivation	3.91	0.92	8
Green organizational culture	3.88	0.93	9
Information technology infrastructure	3.87	0.76	10
Environmental education and training	3.81	0.83	11
Trustworthy teamwork	3.79	0.76	12
Employee involvement	3.75	0.99	13
Compliance statement	3.73	0.85	14
Skilled professionals	3.71	0.91	15
Integration of system	3.70	0.84	16
Performance measurement system	3.69	0.97	17
Technical expertise	3.66	0.90	18
Inter-Departmental cooperation	3.64	1.01	19
Cooperation among suppliers	3.60	0.93	20
Organizational capabilities	3.57	1.03	21
Effective communication platform within companies and with suppliers	3.56	1.05	22
Strict supervision	3.56	0.99	23
Enforcement	3.55	0.90	24
Green purchasing	3.44	1.05	25
Ethical standards and corporate social responsibility	3.41	1.05	26
Green design	3.31	1.14	27
Benchmarking system	3.26	1.09	28
Government support policy	3.15	1.33	29
Collaborative research & development with supplier	2.95	1.39	30
Customer awareness	2.94	1.27	31
Availability of new technology	2.94	1.39	32
Awareness about new technology	2.93	1.38	33
Environmental related programs and meetings	2.92	1.39	34
Supplier adoptability	2.87	1.22	35

4. CONCLUSION

The aim of this research is to study the various GSCMEs and build awareness about these GSCMEs. The nationwide survey of Indian automobile organizations has been conducted to check the status of GSCMEs for successful GSCM implementation. The result shows that Top management commitment and support (4.32), Supplier commitment (4.15), Environmental policy (4.09), Strategic

planning (4.02), GSCM Methodology (3.96) are five most important GSCMEs. These factors should consider more cautiously and in an effective way because these factors provides the complete basis for successful GSCM implementation. The survey approach may be useful to GSCM managers of an organization to employ this model to identify and classify the significant GSCMEs for their needs. This model also reveals the direct and indirect effect

on each enabler on the GSCM implementation. Once these GSCMEs are identified, the top management could formulate a strategy for enhancing their effects during GSCM implementation in automobile industries. Accordingly GSCM managers may also strategically plan its long-term growth strategy to meet GSCM action plan. The outcomes of this study have provided substantial and innovative information by signifying several criteria and a simple, efficient method through which decision makers can improve their capability to analyze the various GSCMEs for successful implementation of GSCM. In addition, the ranking tactics of GSCM implementation show the respondent's observations about the significance of them and helped organizations to identify their strengths to move towards continuous improvement. This study is limited in surveying the status of GSCMEs only in Indian automobile industries. Future study may conduct for some other type of industries in Indian context and in global context.

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Postponement: A Theoretical View

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Abstract: Modern Supply Chain is focused mainly towards customer perception in preparing a product. This requires flexibility towards manufacturing activities. Mass customization is a trend in which the benefit of mass production and product customization both are included. Modern manufacturing is based on the same. Postponement (PP) is a supply chain practice in which final activities in assembly of a product is not performed until customer order arrives. This paper highlights the concepts and perception towards PP. The benefits of adopting PP activities over traditional practices have also been listed. Theoretical analysis of literature is performed to find out the enablers and barriers towards implementation of PP activities. This supply chain activity is a need for the current market competition. This has to be associated with excellent forecasting techniques to remove uncertainty.

Keywords: Supply chain practices, Postponement,

1. INTRODUCTION

In the today's competitive world, companies are focused towards making customer specific products. Producers have developed many supply chain strategies and practices to concentrate on product procreation and meeting customer needs (Kisperska and Swierczek, 2011). Delayed product differentiation is a concept that has helped producers to reduce their inventory requirements and at the same time makes the availability of the product at gross.

Conventionally, mass production was the concept adopted by the companies to get volume benefit. This doesn't support PP activities. Whereas today new supply chain concepts put forward this concept to get a better market share (customers) instead of dumping products into the market. Undeniably, mass production targets large batch type production and benefits of product standardization and not on customization of product(s). Supply Chain Management (SCM), on the other hand, puts forth customer and their preferences thus expanding the purpose of PP.

Mixing the concept of mass production and production customization, companies use concept of mass customization wherein then final structure of the product is delayed to the last possible moment. Mass Customization provides marketing benefit of customization to the manufacturer while bringing in the profit of having standardized products in the outlook of future customer orders.

Postponement is a perception wherein some of the supply chain activities of the product are not performed until customer orders arrives (Van Hoek, 2001). The concept of PP arises because of the increase in demand of the customized products in the market (Kisperska and Swierczek, 2011). Postponement is a concept in SCM where

the manufacturer produces a conventional product, which can be modified at the later stages before the final transport to the customer. One of the classic examples of PP is of paint companies. All the paint companies were initially burdened with maintaining a number of shades (particularly above 150 shades) in inventory which was destroying the business. Later one company came up with a concept that they will produce only white paint and a number of shades can be prepared by mixing up different ratios of basic three colors. This was done at retailer level. When customer demands of a particular color, the retailer just has to mix a fix proportion of color in white paint with the help of a mixing machine. Thus the problem of maintaining inventories of different color bottle was solved. Another example is at the production facility of Dell computers. When booking computers online, Dell provides facility to personalize the computer according to the buyer need of specifications such as processor speed, ram requirement, hard disk size, software and other peripherals (Selladurai, 2004).

Companies facing a high extent of uncertainty, it is a choice of benefit to adopt PP activities. There are various ways to adopt for PP according to the requirement in a particular institution. First step is to reduce process uncertainty as companies get time to go for better manufacturing process and adopt a good transportation network. Second to reduce the uncertainties towards supplier side. Third step is to reduce demand uncertainties for practicing PP over the entire supply chain (Yang and Burn, 2003).

2. POSTPONEMENT: CONCEPTS AND PERCEPTION

The concept of PP is not a new concept. It has not only studied theoretically but is being in practice into industry since late 1950's (Kisperska and Swierczek, 2011). The

concept of PP dates back in late 1960's (Bucklin, 1965), but the main focus toward this turns into late 1990's when a number of papers was being published in various streams such as logistics, strategy operation research etc. (Pagh and Cooper, 1998, Feitzinger and Lee, 1997, Garg and Tang, 1997).

PP has been increased in use by the managers after 1995. It was predicted by Morehouse and Bowersox (1995) that by 2010 more than half of the inventory in various supply chain would be kept in semi-finishedstage and will be

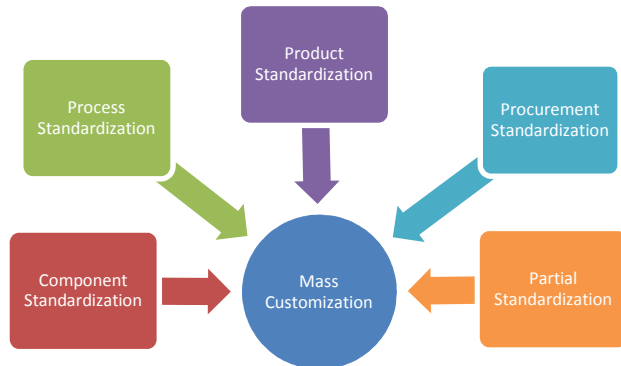


Fig 1. Methods to achieve mass customization. Adapted from Selladurai (2004)

finalized when the order will arrive or rises. In the current market scenario, PP is a necessity to opt for and not a mere concept to be studied (Van Hoek, 2001). Initially PP was studied and understood as, delaying the supply chain activities to as late as possible just to minimize the inventory and the costs associated with it. But now, it is an

integrated management activity in fact there are some supply chain activities that cannot be performed until order from customers are received (Van Hoek, 2001). PP activities are very diversified i.e. it has a very wide range of applications from medical field to engineering to management (Kisperska and Swierczek, 2011). The authors proposed different PP activities according to the amount of delaywhen product gets its final shape and is delivered (Yeung et al., 2007). In terms of production industry, there is manufacturing PP and logistics PP. Manufacturing PP refers to those manufacturing and processing activities that is delayed till the customer's order is received whereas Logistics PP refers to time and place postponement.

Yang and Burn (2003), draws a relationship figuring out Speculation-postponement strategy and standardization-customization concept in a single figure. Engineering to order (ETO) components are purely customized products and can be placed in Pure PP category. Make to order (MTO) components have tailed customization and can be placed in Manufacturing PP. Final manufacturing or assembly to order (ATO) components have customized standardization and can be placed in Assembly PP category. Shipment to order (STO) components holds segmented standardization and thus can be placed in Logistics PP category. Lastly, make to forecast (MTF) products (exhaustible products) which company's make and dump to market are purely standardized products and is placed in pure speculation category.

PP can be beneficial to the companies which are operating worldwide. When demand arrives, companies can customize their products according to demand/ requirement of the customer and the practices being followed in the particular country (Van Hoek, 2001).

TABLE 1: Postponement opportunities (adapted from Van Hoek, 2001)

	Traditional operations	Postponement opportunities in operations
Uncertainties	Limited operations; unpredictability about order mix and volume.	Reduce risk of volume and variety mix bydelaying finalization of products.
Volume	Produce volumes (flow shop) with largeeconomies of scale.	Make batches of one (job shop forcustomization, flow shop elsewhere).
Variety	Create obsolescence risks.	Presume, customize, requiring flexibility.
Lead times	Involve long response times.	Offer accurate response, yet perform activities within order cycle time.
Supply chain approach	Limit variety to gain efficiency advantages.	Reduce complexity in operations, yet possiblyadd flexibility and transport costs.

A number of list of practices are there to achieve mass customization of goods as highlighted by Pine II (1993) and Daugherty (1992) are compiled below. These are total seven in numbers.

- a. Create customizable products and services that can be modified by customers (includes design also.). For example bakery products, self-fitting clothes etc.
- b. Simplify components to promote customizing of finished products and services (including design, manufacturing, distribution and marketing).
- c. The customization should turn around standardized products or services (including logistics and marketing functions).
- d. Reducing the response time in the supply chain i.e. providing quick response (including design, manufacturing, distribution and marketing).
- e. Provide point-of-sale or point-of-delivery customization (involving marketing functions). For

example providing fitting of clothes in store, making different shades of paints in store etc.

- f. Proposing Logistics support to proportional mix (such as sales promotion and public relations).
- g. Proposing tailored logistics service level such as regionally targeted distribution.

3. PROS AND CONS OF POSTPONEMENT

PP is intentionally delaying activities rather than waiting for the demand to arise. Over time PP utilization has surrounded whole supply chain from the product design to manufacturing to dispatch of the same. Forecasting at component level is way better than at final finished product level. It was initially introduced as a strategy to reduce the uncertainty and risk and the costs associated with it. PP concepts have often being used in collaboration with Just in Time concept (Yang and Yang, 2010). The table 2 shows the various impacts of having postponement in the supply chain.

TABLE 2: Operating characteristics relevant to Postponement. (adapted from Van Hoek, 2001)

Factor	Impact of postponement
Technological characteristics	
Limited complexity of final manufacturing operation	Limited loss of economies of scale through postponement and short processing times
Limited complexity of technological content in final manufacturing	Short set-up and changeover times, short processing times
Modularity	Rapid final manufacturing at low processing costs, increased possibility to adjust products to markets
Process characteristics	
Possible to decouple primary and secondary production system	a technical pre-condition and needed for manufacturing within the lead time.
Limited complexity of final manufacturing process	Short set-up and changeover times, short processing times
Sourcing from multiple locations	Direct bulk shipments of modules
Product characteristics	
High commonality of modules	Lowered inventory levels and reduced risk of obsolete inventories
Product variety specific formulation of products, specific peripherals/packaging	Improved customization possible
High value density/unit value of products	Reduced pipeline expenses and inventory carrying costs
Product's cube and/or weight increases through customization/final manufacturing	Reduced transportation and inventory carrying costs
Market characteristics	
Short product life cycles/fashion cycles	Less risk of obsolete inventories
High sales fluctuations	Reduced inventory levels and less risk of obsolete inventories
Short and reliable lead times required	Improved delivery service
Price competition	Lowered cost levels
Varied and (physically) fragmented markets	Better targeting, segmentation, and positioning of products and sales

To avoid the delays caused by PP activities, some of the processes are combined to one or are done parallel or by sequencing activities, thus allowing functional integration. Companies centralize inventories, sometimes to serve a number of countries (as in European Distribution Centres). Sometimes PP reaches to the customer as in do-it-yourself

products (Yang and Burns, 2003). Table 3 shows the key factors in the implementation of PP across supply chain. The various positive effects of PP is highlighted in table 4. Table 5 shows the factors that are threats and have negative impact on a firm.

TABLE 3: Factors affecting the implementation of postponement.

S.No.	Factor	References
1.	Good Information and Communication Technology act as an enabler.	Dröge et al. (1995)
2.	Removing regulatory controls acts as an enabler.	Yeung et al. (2007); Van Hoek et al. (1998a)
4.	Geographical restructuring required for the implementation.	Van Hoek (1998); Yeung et al. (2007)
3.	Market turbulence is a facilitator to PP.	Dröge et al. (1995); Feitzinger and Lee (1997); Van Hoek et al. (1998a)
5.	Operational characteristics should favor postponed manufacturing.	Bucklin (1965); Cooper (1993); Van Hoek (1998); Garg and Tang (1997)
6.	Organizational heritage influences the structure and timetable of change process.	Van Hoek et al. (1998a)
7.	Performance improvements realized through the implementation of postponement.	Feitzinger and Lee (1997); Garg and Tang (1997)
8.	Supplier induced uncertainty should be minimized. Improving flow of material across supply chain.	Yang and Burns (2003); Garg and Tang (1997);
9.	External integration i.e. including customer preferences is a must. Reduces demand uncertainty.	Yang and Burns (2003); Feitzinger and Lee (1997)

TABLE 4: Advantages of Postponement activities across Supply Chain.

Positive influence of Postponement	References
Customer preference and customization of products.	Van Hoek (2001); Daugherty et al. (1992);
Avoid inventories build up in warehouses in anticipation of future demand.	Van Hoek (2001); Selladurai (2004);
Transportation is avoided in between shop floor to warehouse.	Van Hoek (2001); Bucklin (1965); Cooper (1993)
Products directly shipped to customer.	Van Hoek (2001); Pine (1993);
Useful for products that can't be stored (keeping it as inventory cost is more than transportation cost) (more value added products)	Van Hoek (2001); Pagh and Cooper (1998); Simao et al. (2016)
Avoids confusion in specification of products thereby enhances efficiency of activities.	Van Hoek (2001)
Postponement calls for reducing the uncertainty induced by the bullwhip effect.	Yang and Burns (2003); Garg and Tang (1997)
Help supply chains upgrade their capabilities toward the hard-to-copy or hard-to-diffuse domains, thereby creating a competitive advantage	Yang and Burns (2003); Kisperska and Swierczek (2011)
Reducing the environmental impact of CO ₂ emissions from transportation process.	Simao et al. (2016)
PP reduces overall risk of product failure.	Yang and Yang (2010);
PP helps making information flow better in supply chain.	Feitzinger and Lee (1997); Yang and Burns (2003)
Supply Chain Integration.	Yang and Burns (2003); Kisperska and Swierczek (2011)
Reduces process uncertainty.	Yang and Burns (2003); Kisperska and Swierczek (2011)

TABLE 5: Disadvantages and threats associated with Postponement activities

NEGATIVE INFLUENCES OF POSTPONEMENT	REFERENCES
Control of the supply chain is a prerequisite for postponement applications.	Yang and Burns (2003);Pagh and Cooper (1998);
Tighten the control include adopting information technology to link operations to suppliers and customers.	Yang and Burns (2003);Simão et al. (2016)
Implementation of postponement leads to reducing economies of scale and increasing cycle time.	Yang and Burns (2003);
Extensive use of postponement brings a big challenge to the control over the supply chain.	Pagh and Cooper (1998); Yang and Burns (2003);
Implementing PP strategies is a very complex issue.	Yang and Yang (2010); Van Hoek et al. (1998a);
Lead time may restrict postponement activities.	Van Hoek (2001);
For postponement to work, uncertainties in the supply chain have to be reduced as much as possible.	Sreedevi and Saranga (2017); Yang and Burns (2003);
Supplier delivery performance has to be high.	Van Hoek et al. (1998a); Yang et al. (2005);
Direct customer interaction to be there for avoiding confusion in the requirements.	Yang et al. (2005); Van Hoek et al. (1998a);
Culture and organization change.	Yang et al. (2005);Yeung et al. (2007)
Involvement of suppliers in engineering and operation.	Yang et al. (2005);
Operational Control to be strict.	Pagh and Cooper (1998); Yang et al. (2005);
Market Policies to be flexible.	Yang et al. (2005);Yeung et al. (2007)
Incompatible communication/information system with suppliers and customers.	Sreedevi and Saranga (2017); Yang et al. (2005);
Intricate and direct distribution.	Yang et al. (2005);
Implementation would be too costly.	Yang et al. (2005);
Government Regulations.	Yeung et al. (2007); Yang et al. (2005)
Firms that have high environmental uncertainty are exposed to high supply risk, high manufacturing process risk and high delivery risk.	Sreedevi and Saranga (2017); Pagh and Cooper (1998); Yeung et al. (2007)

4. CONCLUSION

The Postponement has emerged as one of the most essential supply chain activity from the past decade (Sreedevi and Saranga, 2017). This practice is being listed in the literature in the early 60's till today. To be in the market competition today, the companies are forced to provide a number of options in products and also had to provide a high level of customization. These all factors bring major uncertainties in the entire supply chain. If the company is not able to cope with these uncertainties, the entire supply chain will crumble due to high market pressure and competition. This paper will clear the perception about PP activities highlighting its various benefits by comparing with traditional manufacturing. Factors affecting implementation, the benefits and deprivation are further listed at the later stage.

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Identifying the Success Factors of Remanufacturing Supply Chain and Prioritizing using AHP

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Abstract: Increased industrialization in the last decade is creating significant pressure on manufacturers to focus on environmental management. Organizations under no condition ignore the environmental issues and in fact have started searching for sustainable solutions. Remanufacturing supply chain (RSC) helps organization reduce their environmental risks thereby improving their environmental performance and also provides competitive advantage in the market. Selecting the criteria for RSC performance measurement is a strategic decision. Many studies have been carried out to identify the success factors for RSC; however there exists few when it comes to weighing of each criterion according to its importance. The present study first identifies the success factors for RSC through literature study. However, each of these drivers will have varying weightings in the decision making process. Further an Analytical Hierarchy Process (AHP) technique is used to determine the importance of each criterion. Expert opinion in the proposed field has been taken to demonstrate the methodology.

Keywords: Remanufacturing Supply Chain (RSC), Critical Success Factors (CSFs), Analytical Hierarchy Process (AHP)

1. INTRODUCTION

Environment, the natural provider of resources and also the sink to dispose the end-of-life/end-of-use products and waste is being exploited due to unethical human activities in the last few years, thus resulting into an unsustainable environment. There is increasing need that the manufacturing industries address these problems and tend to increase their production with minimum use of raw materials and natural resources, thus addressing the sustainable issues in the manufacturing activities. Manufacturers need to come out of the traditional thinking and incorporate sustainable strategies in their activities to reduce wastage. This is why manufacturing firms, especially original equipment manufacturers (OEMs) and their suppliers, are under increasing pressure from stakeholders, including regulators, customers and employees to produce ethically, reuse/recycle, remanufacture, and/or to safely discard their waste in accordance with the absorptive and regenerative capacity of the planet (Barker and Zabinsky, 2011).

Researchers attempt to address the above issues by developing different sustainable strategies such as modular design, cleaner production (Xia et al., 2015) and reuse and recycling (Wu et al. 2017). Undoubtedly these strategies best support sustainability but in the last few years, remanufacturing is one such strategy that is finding increased attention in the research community (Goepp, Zwolinski, and Caillaud 2014; Radhi and Zhang 2016). Remanufacturing is a multi-process that involves product

recovery after its end-use, inspection, disassembly, cleaning, refurbishing, reconditioning, upgrading, and reassembly to transform the used product to a “like-new” product (Sutherland et al. 2008; Ke et al. 2011; Kafuku et al. 2016). Remanufacturing has gained attention from research community as well as industrial practitioners due its several advantages such as: eco-efficiency and effectiveness of asset recovery (Nasr and Thurston, 2006); improved profit margins (Wei and Zhao 2015; Diaz and Marsillac 2017; Loomba and Nakashima 2012); and saves the resources along with reduction of emissions to the environment (Yang et al., 2015).

However, there is still a serious concern when it comes to implementation of remanufacturing in Indian industries. Successful implementation of remanufacturing in the existing supply chain is relatively difficult from industrial point of view as most of the industries are unknown of the benefits that can be accrued due its implementation and also lack of standardized process to initiate it (Chan and Kai Chan, 2008). In addition, remanufacturing decision makes the entire system more complicated due to complex relationship between the forward and reverse flow of products. To deal with this uncertainty, scholars and practitioners attempt to isolate the important determinants of initiation and implementation of RL among industries (Vijayan et al., 2014). A study is thus needed to identify the essential critical success factors for remanufacturing implementation in the existing supply chain.

Remanufacturing supply chain being multi-faceted and further an attempt to implement it demand to identify key critical success factors. These factors share a complex interrelationship amongst them. Also, the factors for successful implementation of remanufacturing in supply chain may turn out to be either qualitative or a few quantitative, hence a suitable technique is very much needed to handle the complex situation of a multi-dimensional problem. Under such circumstances, it is most appropriate to make use of multi-criteria decision making (MCDM) techniques due to its ability to handle complex parameters at a time.

In this regard the paper aims to study the remanufacturing supply chain with the following objectives:

1. To identify the critical success factors for remanufacturing implementation in supply chain.
2. Analyze the drivers using Analytical Hierarchy Process (AHP).

Analytic Hierarchy Process (AHP) a multi-criteria decision making tool, has been identified to quantitatively analyze the relative significance of the drivers to implement green supply chain. AHP methodology helps top management identify the priority success factors of RSC as it divides complex problem into simple problems using a multi-level hierarchical structure; each level representing set of criteria and sub-criteria.

The rest of the paper is organized as follows: Section 2 covers the literature review on RSC that plays a major role in identification of success factors of RSC implementation. Four important dimensions have been identified in this study. Solution methodology is explained in Section 3. Section 4 consists of data analysis and presents the results. Findings of the results and concluding remarks are discussed in section 5.

2. LITERATURE REVIEW

Literature related to remanufacturing supply chain is discussed in this section. This section is divided into two subsections. The first provides the relevant literature on remanufacturing implementation while the second subsection identifies the drivers of RSC through the study of existing literature.

2.1 RSC

Few studies carried out in Indian context with a focus on remanufacturing are discussed in this section. Mondal and Mukherjee (2006) based on empirical study identifies six critical factors that Indian manufacturers consider before they make their decision to engage into remanufacturing activities or not. Choudhary and Singh (2011) explore the potentiality of remanufacturing growth in India and the challenges that may be faced by the industry, environment and society during its implementation. Rathore et al., (2011) evaluates the present remanufacturing status through a case analysis of India mobile phone to find ways as to how in the present socio-economic environment it can be successfully implemented. Govindan et al., (2016) study is focused on Indian auto parts remanufacturing industries to evaluate the critical barriers. They propose a hybrid approach (ISM-Fuzzy ANP) for analysis.

2.2 Remanufacturing implementation: critical success factors

Effective and efficient implementation of remanufacturing supply chain practices depends on the factors that should be evaluating its performance. The study identifies eight major success factors identified through literature review and subsequent discussion with SC experts, academicians, and industrial practitioners (Senior level, Middle level managers). The identified eight success factors are as described in Table I.

TABLE I: Common critical success factors for implementation of Remanufacturing in a SC

Criteria	Criteria code	Description	Source
Management commitment and involvement	RSC1	Intensify remanufacturing implementation and better coordination and involvement	Subramonium et al., (2013)
Standardized policies from government	RSC2	Provide an organized approach to small enterprise and new organizations through a standardized framework	Sharma et al. (2016)
Effective information flow	RSC3	Proper coordination at each stage of the remanufacturing supply chain	Vasanthakumar et al., (2016)
Technological up-gradation	RSC4	Improve product quality and productivity	Mondal and Mukherjee (2006)
Expertise training	RSC5	Efficient handling of remanufacturing complex production environment	Rathore et al., (2011)
Healthy work environment	RSC6	Increase worker efficiency	Rathore et al., (2011)

Criteria	Criteria code	Description	Source
Research and development	RSC7	Improves product performance and reduce hazard material	Abdulrahman et al. (2014)
Material durability	RSC8	Enhance service life of the components	Abdulrahman et al. (2014)

3. SOLUTION METHODOLOGY: ANALYTICAL HIERARCHY PROCESS

The concept of AHP was developed by an American mathematician, Thomas L. Saaty from the University of Pittsburgh (Saaty, 2008). For various decisions making process Analytical Hierarchy Process (AHP) is one of the

most frequently applied multi-attribute decision making methods.

Steps of AHP Methodology: (1) Identifying the drivers (criteria) and structuring the criteria hierarchy.

(2) Compare the criteria pair wise. (3) Calculating the consistency ratio (4) Calculate the overall priorities of criteria and sub-criteria and identify the important drivers.

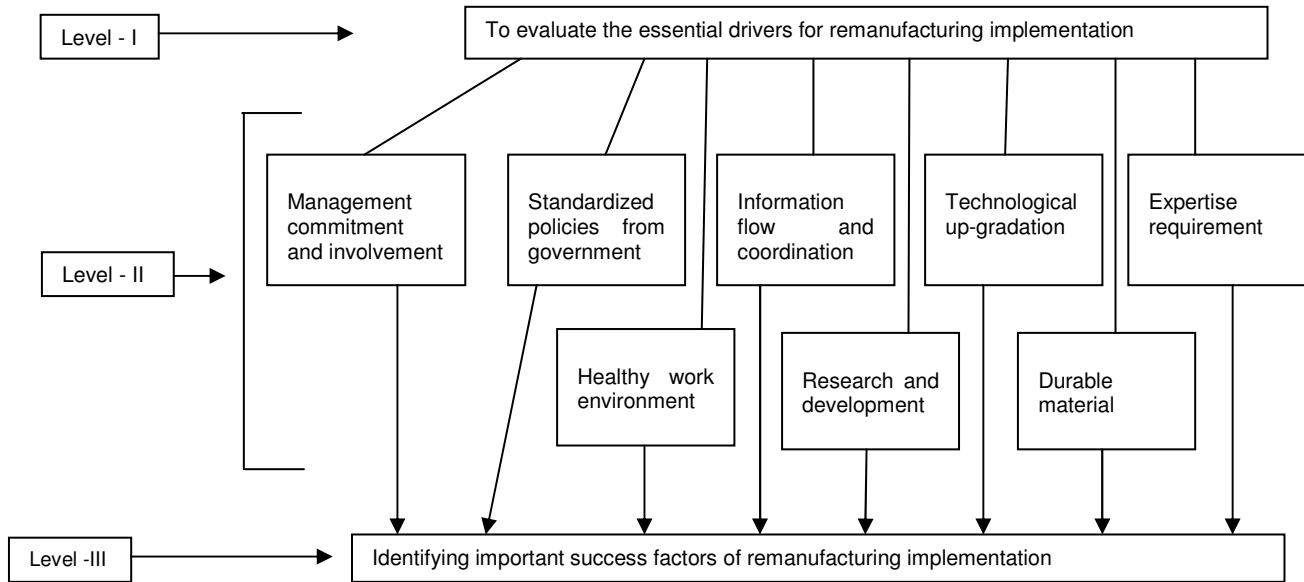


Fig. 1 AHP Hierarchy to identify important success factors for remanufacturing implementation

4. DATA ANALYSIS AND RESULTS

Expert opinion is taken for pair wise comparison of matrix at each level of the hierarchy. The maximum Eigen values, C.I. and the priorities of each criterion as obtained by pair wise comparison. One sample of criteria comparison at each Level I and Level II is shown in Table II.

TABLE II: Pair wise comparison matrix for each level of hierarchy

	RSC1	RSC2	RSC3	RSC4	RSC5	RSC6	RSC7	RSC8	Weights
RSC1	1	3	5	3	3	5	3	7	0.2953
RSC2	0.333	1	5	3	4	5	3	6	0.2279
RSC3	0.2	0.2	1	0.25	4	5	0.2	6	0.0808
RSC4	0.333	0.333	4	1	3	4	0.333	5	0.1152
RSC5	0.333	0.25	0.25	0.333	1	3	0.25	4	0.0531
RSC6	0.2	0.2	0.2	0.25	0.333	1	0.2	3	0.0321
RSC7	0.333	0.333	5	3	4	5	1	7	0.1754
RSC8	0.143	0.167	0.167	0.2	0.25	0.333	0.143	1	0.0202

CR ≤ 0.1

TABLE III: Normalized weights for success factors for RSC implementation

Drivers (Level I)	Weightings using AHP	Rank
RSC1	0.2953	1
RSC2	0.2279	2
RSC3	0.0808	5
RSC4	0.1152	4
RSC5	0.0531	6
RSC6	0.0321	7
RSC7	0.1754	3
RSC8	0.0202	8

5. DISCUSSION AND CONCLUSION

The present work identifies the success factors of RSC implementation through literature study and demonstrates the use of AHP to evaluate the importance of each driver. Eight main dimensions (Table I) were identified that plays vital role in adoption of remanufacturing practices in a supply chain.

AHP methodology is used to identify the percentage contribution of each criterion. The normalized weight matrix of each criterion (Table III) indicates that the priority weight for management commitment and involvement (0.2952) followed by standardized policies from government (0.2279) are some of the most important practices that needs to be implemented for successful implementation of remanufacturing in a supply chain. The study helps the decision makers to identify the important factor that should be focused to achieve the organizational goal and improve their sustainable performance.

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Ranking the Solutions of Information Sharing Adoption in Supply Chain to Overcome its Barriers

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Abstract: Supply chain partnership leads to increased information flows, reduced uncertainty, and a more profitable supply chain. Effective supply chain practice and information sharing enhances the current supply chain management environment. Effective information sharing significantly enhances effective supply chain practice. Information exchange is a very important issue for coordinating actions of units. Accurate and reliable information is needed to support decision-making processes. Due to the large number of participants typically involved in supply chain operations, organizations often find that it is difficult to effectively share information within a supply chain; hence, this research examined ways to improve information sharing within supply chain operations for one marine transportation services organization. The AHP is a flexible multi-criteria decision-making method which can be used to effectively synthesize the judgments given by a team of experts in order to make better decisions in complex settings, where both tangible and intangible criteria must be considered. It is a powerful decision-making methodology for determining the priorities among number of different criteria.

Keywords: Information Sharing, Supply Chain, Supply Chain Management, Fuzzy AHP, Barriers, Major-criteria, Sub-criteria, Decision maker.

1. INTRODUCTION

Because of globalization, serious rivalry and innovative blast as of late, it is critical to viably arrange a wide assortment of associations by sharing essential data (Pujara et al., 2012; Yee, 2005). The information sharing is an all-around acknowledged method where associations by and large compose the supply, generation, and circulation of items and administrations (Chandra et al., 2007). The side effect of information sharing on supply chains (SC) has passed out to be more critical with late approach in Information Technology (IT). Besides, a few examinations have been led to concentrate on the effect of information sharing on item aspect (Lotfi et al., 2013). To upgrade the after effects of information sharing, management ought to answer four fundamental queries: First we ask that what to share, then whom to share with, then how to share, lastly when to share. The description of answers will dodge repetition, lessen sharing expenses and enhance reactions (Robinson and Sahin, 2005). IS allows to the sharing of private and optional information, which is past the information required to complete the everyday exchange

among purchasers and merchants (Yigitbasioglu and Organ, 2010).

2. LITERATURE REVIEW

The coordination of an organization supply chain with numerous providers, with which information sharing is crucial or important, since it can frequently improve the execution of the supply chain, yet may build up and strengthen the opposition among individuals in the chain (Ho et al. 2017). Information sharing in a SC comprising of one provider and one retailer, in which both of them two estimate the request under make-to-stock and make-to-request situations (Mishra et al. 2009). In current business; rivalry is no longer between organizations, yet among supply chains. Supply chain is unpredictable in nature, including different work streams crosswise over exchanging accomplices (Wu et al. 2014). The impact of information sharing among business accomplice's on-time conveyance rate and aggregate cost is researched by means of recreation of a nonspecific, speculative supply chain model (Hall et al. 2012)

TABLE 1 Initial hierarchy model of barriers of IS adoption in SC and its criteria

Main criteria	C. code	Sub criteria	References
Strategic barriers	SB 1	Lack of customer oriented vision	Costantino et al. (2015); Wo et al. (2014)
	SB 2	Lack of Strategic planning	Bain et al. (2016); Bonzon et al. (2016)

Main criteria	C. code	Sub criteria	References
	SB 3	Lack of IS between SC members	Pujara et al. (2013)
	SB 4	Lack of SC benefits	Manzouri et al. (2010)
	SB 5	Lack of SC integration	Zhor et al. (2007)
	SB 6	Inadequate clear understanding of IS	Prakash et al. (2015)
Organizational barriers	OB 1	Deficiency of improved mutual sharing trust	Ye et al. (2013)
	OB 2	Improper organization structure	Manzouri et al. (2011); Parcin (2008)
	OB 3	Lack of top management support	Senthil et al. (2012); Costantino et al. (2015)
	OB 4	Improper flow of information	Prakash et al. (2015)
	OB 5	Lack of enhanced adaptability	Jeong et al. (2012)
	OB 6	Long term relationship among supply chain members	
	OB 7	Diminishing organization power	Singh et al. (2008)
Financial barriers	FB 1	Shortage of fund for training and education	Zhang and Chen (2013)
	FB 2	Required resources for operational use	Sohal et al. (2012)
	FB 3	Inadequate fund related offices for equipment	Ganesh et al. (2014)
	FB 4	Lack of cost sharing benefits	Parcin (2008)
Technological barriers	TB 1	Inefficient technological advancement	Cheung et al. (2012); Gunasekaran and Ngai (2004)
	TB 2	Risk of data loss	Kumar et al. (2012); Kaynak et al. (2012)
	TB 3	Trouble in classifying strategy information	Kembra et al. (2015); Lotfi et al. (2013)
	TB 4	Absence of service exchange	Lee et al. (2006)
Human-based barriers	HBB 1	Lack of employee motivation and reward	Bouzon et al. (2016)
	HBB 2	Confidentiality of the SC information shared	
	HBB 3	Lack of supportive culture	Ganesh et al. (2014); Pujara et al. (2013)
	HBB 4	Lack of time to share information	Lau et al. (2009)
	HBB 5	Fear of shame for sharing wrong data	Pillai et al. (2010); Willem et al. (2007)

3. FUZZY AHP APPROACH

Computational technique of fuzzy analytic hierarchy process. The analytic hierarchy process strategy is otherwise called an eigenvector strategy. It shows that the eigenvector relating to the biggest eigen-value of the pair wise examinations matrix gives the relative needs of the components and preserves ordinal desire among the options. This implies if an option is wanted to another, its

eigenvector part is bigger than that of the other. A vector of weights gotten from the pair wise examinations matrix mirrors the relative execution of the different components. In the Fuzzy AHP, TFNs are used to enhance the scaling plan in the judgment frameworks and interim math is utilized to unravel the fuzzy eigenvector (Cheng et al, 1994). Below table is used for pairwise comparison for criteria

TABLE 2: Linguistic variable for solutions ratings.

Intensity of importance	Fuzzy number	Linguistic variables	Membership function
1	$\tilde{1}$	Equally important/preferred	(1, 1, 3)

Intensity of importance	Fuzzy number	Linguistic variables	Membership function
3	$\tilde{3}$	Weakly important/preferred	(1, 3, 5)
5	$\tilde{5}$	Strongly more important/preferred	(3, 5, 7)
7	$\tilde{7}$	Very strongly important/preferred	(5, 7, 9)
9	$\tilde{9}$	Extremely more important/preferred	(7, 9, 11)

The next step is to build fuzzy comparison matrix by utilizing the above TFN table with the help of industrial experts. Since due to space limitation only one FCM are shown here similarly same approach is applicable for all major and sub criteria.

TABLE 3: FCM for major criteria

Attributes	Strategic	Organizational	Financial	Technological	Human-based
Strategic	1	$\tilde{1}^{-1}$	$\tilde{5}$	$\tilde{1}$	$\tilde{7}$
Organizational	$\tilde{1}$	1	$\tilde{7}$	$\tilde{3}$	$\tilde{9}$
Financial	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{1}$
Technological	$\tilde{1}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	1	$\tilde{5}$
Human-based	$\tilde{7}^{-1}$	$\tilde{9}^{-1}$	$\tilde{1}^{-1}$	$\tilde{5}^{-1}$	1

The overall consistency (CR) ratio of all criteria matrix and all over inconsistency for the hierarchy can be analysis and control the overall result of this approach. The CR value can be found out as:

Determine the highest Eigen value by utilizing the below equation.

$$\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x}$$

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Where CI represents consistency index and RI is random index. The value of RI can be taken as per the table shown below.

TABLE 4: Random index value

n	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

If the CR for a comparison matrix is less than 0.10 then the comparisons are acceptable, otherwise not. If the value does not found to be less than 0.10 then decision maker has to revise the authentic values in the pair wise comparison

matrix. And finally rank the barriers by giving weight to them in decreasing order.

4. APPLICATION ON CASE ORGANIZATIONS

In today's scenario many Indian manufacturing organizations understand that IS plays a crucial role for success of business and IS adoption in SC is going to be a core importance. Some manufacturing organization have taken IS integration with SC. But the rate of success was quit low due to presence of barriers in IS adoption in SC. In order to increase the rate of success the main thing is to shortlist these all barriers and rank them as per there priorities. Since implementing all criteria at the same time which is a tough task. Hence it is crucial to rank these barriers of IS adoption in SC, hence, manufacturing organization can put on barriers and implement in a proper stepwise sequence. The case organization X, interesting in implementing information sharing because it suffers pressure from current competitive challenges from others organization which is dealing with the same operation. Organization X is an Indian manufacturing company with turnover of more than 52crores and over 500 employees and 25 suppliers and venders. Organization engaged in design, manufacturing, and marketing of electrical equipment related to power generation, transmission, and distribution. This company shows interest to find out and rank the barriers of IS adoption in SC. Below table shows the weight of major criteria similarly weight of all sub criteria can be calculated.

TABLE 5: Final weight for major criteria

Major Criteria		Major Criteria Weight
Strategic barriers	=	0.286108049
Organizational barriers	=	0.427783903
Financial barriers	=	0.060639471
Technological barriers	=	0.183572216
Human-based barriers	=	0.041896362

The judgment for ISBs display has been dissected with the assistance of CR and discovered logical as it is satisfying the situation yet in the event that some way or another it neglects to satisfy the situation for the consistency then

expert need to replay the pairwise observation prepare until the situation for consistency has been come to. After the consistency test for matrix 'A', standardization of the GCCMmaj is finished. The significant criteria weights are condensed: Strategic barriers (0.2061), Organizational barriers (0.4277), Financial barriers (0.0606), Technological barriers (0.1835), Human-based barriers (0.0418).

By taking after the comparative figuring, fuzzy comparison matrices for sub criteria were changed into crisp correlation matrix and their significant standard weight, CR, proportion weight for Strategic barriers, Organisational barriers, Financial barriers, Technological barriers, Human-based barriers. There were ascertained utilizing PC program.

TABLE 6: Final priority of Information Sharing Barriers

Main Criteria	Major Criteria Weight	Sub Criteria Code	CR	Ratio Weight	Final Weight	Rank
Strategic barriers	0.2861	SB 1	0.0803	0.14989	0.04288	9
		SB 2		0.4415	0.12633	2
		SB 3		0.0790	0.02260	13
		SB 4		0.04599	0.01315	17
		SB 5		0.2570	0.07353	5
		SB 6		0.02651	0.00758	22
Organizational barriers	0.4277	OB 1	0.0886	0.0650048	0.02780	12
		OB 2		0.2394916	0.10245	3
		OB 3		0.3758553	0.16078	1
		OB 4		0.0405669	0.01735	14
		OB 5		0.0249266	0.01066	20
		OB 6		0.1011730	0.04328	8
		OB 7		0.1529814	0.06544	6
Financial barriers	0.06063	FB 1	0.0636	0.5738125	0.06544	10
		FB 2		0.2586649	0.03479	15
		FB 3		0.1168164	0.01568	23
		FB 4		0.0507060	0.00708	25
Technological barriers	0.1835	TB 1	0.0961	0.4563835	0.00307	4
		TB 2		0.2963604	0.08377	7
		TB 3		0.1842865	0.05440	11
		TB 4		0.0629693	0.03382	18
Human-based barriers	0.04189	HBB 1	0.0445	0.2336787	0.00979	21
		HBB 2		0.0813471	0.00340	24
		HBB 3		0.3637305	0.01523	16
		HBB 4		0.2689119	0.01126	19
		HBB 5		0.0523316	0.00219	26

Last weight of the sub criteria can be computed by multiplying the major weight of each ISB and proportion weight of each ISB.

5. RESULTS, DISCUSSIONS, CONCLUSIONS AND FUTURE SCOPE

It is difficult to state beyond any doubt which barriers of IS selection in SC is very crucial, yet the positioning procedure by utilizing fuzzy AHP methodology made it extra extensive and organized. This method utilized as a part of an Indian manufacturing was planned to enhance the achievement amount of IS selection in SC. This will be accomplished by actualizing the result of IS selection in SC by stepwise way to blown-away its barriers. Ultimately total 26 are distinguished by writing audit and decision maker request. The weight of the hurdles of IS selection in SC figured by fuzzy AHP and based upon their value ranking had been done in decreasing order.

The ISBs have been summed up and might be lacking or certain for some particular industries. This procedure may observe to be useful for directors to touch base at basic ISBs for their businesses. The overall results shows that the combination of fuzzy decision making with AHP could become a useful tool in future research. For the future research, fuzzy system could be stretched out with the other MCDM strategies, for example, Analytical Network Process (ANP), TOPSIS.

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Coordination of Production and Distribution Planning for a Supply Chain with Third Party Logistics

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Abstract: With growing complexity in supply chains, it became necessary to incorporate these complexities into the models. In this paper, the authors propose a model for coordination of production and distribution planning for a supply chain with third party logistics. In 3PL, the transportation facilities (vehicles) are owned by private parties (i.e. they are not owned by plant owners). In this type of distribution, the plant managers and distribution service providers share partial information. They will not share information about their capacities and costs, because of lack of trust. But share information such as the desired production quantity by the distributors and possible production quantity by the plant managers. Under such situations, the model proposed in this paper is appropriate. The authors tested the model for problems generated with uniform random numbers between minimum and maximum values for the costs and capacities. The results indicate that the proposed model can be applied to real life problems where third party logistics are involved.

Keywords: Multi Product SCM, Agents in SCM, Third Party Logistics, 3PL

1. INTRODUCTION

The production – distribution planning models of supply chains can be considered broadly as two types. In the first types of models there is complete information sharing and the channel partners (production managers and distributors (transporters) share complete information between them. The distributors and manufacturers share information about their capacities and costs. In this type of supply chain models, there is single objective function which minimizes the sum of distribution related and production related costs subject to constraints on plant and inventory capacities and inventory balance constraints. This type of models is appropriate when the transportation facilities (vehicles) are owned by the plant owners.

In the second type of models, there is partial information sharing between the distributors and manufacturer's. The distributors will not share information about distribution costs, and distribution capacities. But they will share information about desired production quantity required from the manufacturers to minimize their distribution costs. Similarly the manufacturers will not share information about production capacity and production costs but will share information about possible production quantity, to the distributors, considering their plant capacities. In this type of supply chain models, there are two objective functions, one each for distribution and production, to minimize their respective costs. In addition, there is a coordinating mechanism which modifies the capacities of production and distribution according to an algorithm. Each of the

production and distribution problems is modeled as an agent. Each agent has an objective and there is only partial information sharing between the two agents. Each agent tries to locally optimize its own objective function. Finally there is a coordination mechanism between the two agents to arrive at the final optimal plans for production and distribution.

The Paper is organized as follows. Brief literature review is carried out in section.2. The proposed model is presented in section.3. The methodology is presented in section.4. The data set used in this paper is presented in section. 5. Implementation details are mentioned in section. 6. Results are discussed in section. 7. Finally the paper concludes in section 8..

2. LITERATURE REVIEW

Hosang Jung (2005) et al has proposed a decentralized production-distribution planning system using collaborative agents in supply chain network. In their work, they considered two agents, one each for production and distribution functions.

Tatsushi Nishi (2006) et al has proposed an autonomous decentralized supply chain planning and scheduling system in which three autonomous agents are used to represent the material requirement planning (MRP), Scheduling and Distribution planning (DP) functions of a supply chain .

Martin Albrecht (2015) et al has proposed a system of coordinating decentralized linear programs by exchange of

primal information. The authors have mentioned, that exchanging primal information, rather than the dual information has the advantage that the plant managers know about what information they are exchanging.

KavehKhallili (2016) et al has considered uncertainty in demand and formulated centralized and decentralized production distribution planning problem in supply chain with uncertainty. They used fuzzy mathematics to model the uncertainty in demand at the retailer..

3. PROPOSED MODEL

The proposed model consists of three echelons (levels), namely plants, Distribution centers (warehouses), and customer zones. The problem is modeled by two software agents (two linear programs), one each for distribution and production.

3.1.DISTRIBUTION AGENT(DA)

The Costs of DA include distribution related costs like tardiness costs, earliness costs, distribution costs from plant to warehouses, and distribution costs from warehouses to customer zones. Tardiness costs are incurred when a product is delivered after its' due date. The tardiness costs reflect the reputation and goodwill lost by the firm by delivering a product after its due date. Earliness costs are incurred when a product is delivered before its' due date. The objective of distribution agent is to minimize the sum of tardiness cost, earliness cost, distribution costs from plants to distribution centers and from distribution centers to customer zones for all the products in all periods. The distribution agent will minimize his objective function subject to constraints such as meeting the demand at customer zones, Inventory balance constraints and limit on maximum earliness quantities. That is, the Distribution agent (DA) is a linear program

3.2.PRODUCTION AGENT(PA)

The production related costs include the manufacturing costs, inventory holding costs and stock out costs. The objective of Production agent (PA) is to minimize the sum of production related costs mentioned above. The PA will minimize the production related costs subject to constraints on inventory balance constraints, production and inventory capacity constraints. The shortage costs are fixed at a high value so as to prefer production to shortage situation

4. METHODOLOGY

Initially, the distribution agent will minimize the distribution related costs subject to its' own constraints. During this process the DA will not consider the plant capacity constraints. The DA will communicate to PA, the **desired production quantity**. The **desired production quantity** for a given product at a given plant in a given time period is calculated as the sum of distribution quantities of

that product in that period from all distribution canter to that plant. This **desired production quantity** is communicated by the DA to PA. Now the PA will use this **desired production quantity** and production and inventory capacity constraints to minimize production related costs. That is the PA will determine the **possible production quantity**. Using this **possible production quantity**, the **plant capacity** is **modified** according to an algorithm. This **ModifiedPlant Capacity** is communicated to the DA and the DA will minimize the distribution related costs with the addition of the new constraint that the **distribution quantity** of all products between plant and distribution centre in a given period will not exceed the **Modified Plant Capacity**. The variables that are exchanged between the DA and PA are shown by bold letters. This iterative exchange of information between the DA and PA is continued until there is no planning gap. That is the desired production quantity is not greater than the possible production quantity.

5. DATA SET

In this Paper, for implementation purpose, a supply chain with two plants, two distribution centers and four customer zones is assumed. Each plant is assumed to produce 8 products. The time horizon for the problem is 12 periods.

Four test problems with different costs (seven costs – Four costs for DA and three costs for PA) and capacities (three capacities – plant capacity, inventory capacity, and limit on earliness quantity) have been generated with uniform random integers between minimum and maximum values. The ranges of these values have been shown in Table.1.

6. IMPLEMENTATION

The proposed model has been modelled in General Algebraic Modelling System (GAMS 24.7.4) software. CPLEX MIP solver has been used to solve all the test problems

7. RESULTS

The summarized results for all the four test problems have been shown in pie charts for test problems 1, 2, 3, 4 in iteration no.1 and 15. The summarized results for all the four test problems are also shown in Table.2 for test problems 1, 2, 3, 4 in iteration no.1 and 15. In Table.2 the share of each channel in total cost is shown for iteration.1 and iteration.15.. As can be seen from the table, the share of DA in total cost is increasing and that of PA is decreasing. This behaviour is due to the negotiation between the two agents, DA and PA.

The share of each channel (DA, PA) in the Total costs is shown in pie chart. In Fig.1 and Fig.2.The convergence graph of the algorithm is shown in Fig.3.. In Fig.3, iteration No. is taken along the x axis and DA Cost, PA Cost and Total Cost values are shown on the y axis.

8. CONCLUSION

In future, the proposed model is going to be implemented in MATLAB by solving the model with different Meta heuristics such as GA, PSO, ABC, etc. and a comparison will be made.

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TABLE 1: Parameters values ranges

Parameter	Test Problem No.1	Test Problem No.2	Test Problem No.3	Test Problem No.4
Demand	This Parameter is taken as constant for the four Problems			
Tardiness Cost	[1000, 2000]	[1000, 2000]	[1000, 2000]	[50, 150]
Earliness Cost	[150, 250]	[1000, 2000]	[1000, 2000]	[10, 100]
Distribution cost from plant to Distribution center	[150, 250]	[100, 150]	[100, 1500]	[10, 50]
Distribution cost from distribution center to customer zone	[[300, 500]	[50, 500]	[50, 500]	[50, 200]
Production Cost	[2000, 3000]	[1000, 8000]	[1000, 8000]	[1500, 3000]
Inventory holding cost	[1000, 1500]	[150, 1500]	[150, 1500]	[150, 500]
Shortage cost	[5000, 6000]	[25000, 30000]	[25000, 30000]	[5000, 6000]
Plant Capacity	[10000, 15000]	[100, 200]	[4000, 5000]	[100, 150]
Inventory Capacity	[4000, 5000]	[50, 500]	[50, 500]	[250, 500]
Maximum Allowable Earliness	[3000, 4000]	[100, 200]	[100, 200]	[100, 150]

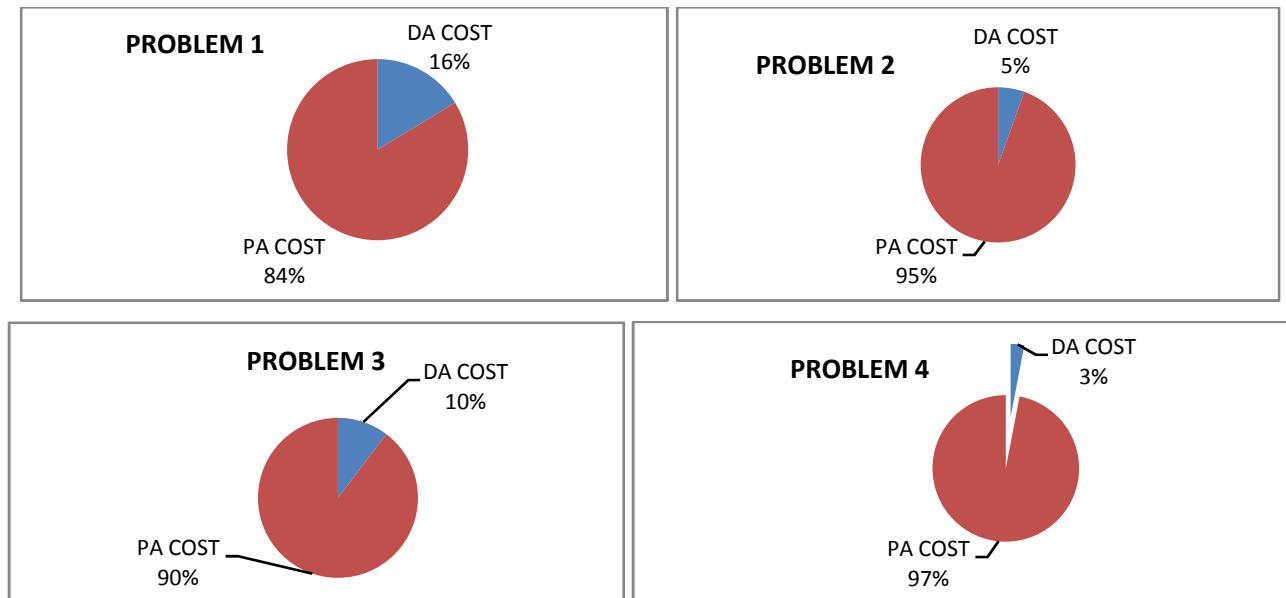


Fig. 1: The Share of each Channel in Total Cost (Problems 1, 2, 3, 4)

1 st Iteration

TABLE. 2: Share of each Channel (DA and PA) in Total Cost

1 st IterationChannel	Problem No.1		Problem No.2		Problem No.3		Problem No.4	
	Iteration 1	Iteration 15	Iteration 1	Iteration 15	Iteration 1	Iteration 15	Iteration 1	Iteration 15
DA	16%	25%	6%	93%	9%	45%	4%	91%
PA	84%	75%	94%	7%	91%	55%	96%	9%

1 st iteration and 15 th iteration

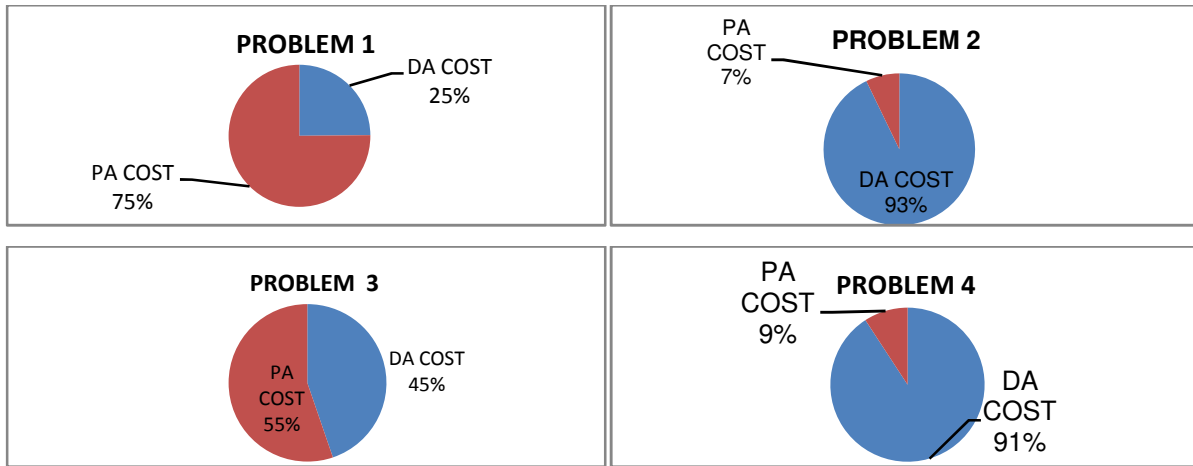


Fig. 2: The Share of each Channel in Total Cost (Problems 1, 2, 3, 4)

15th Iteration

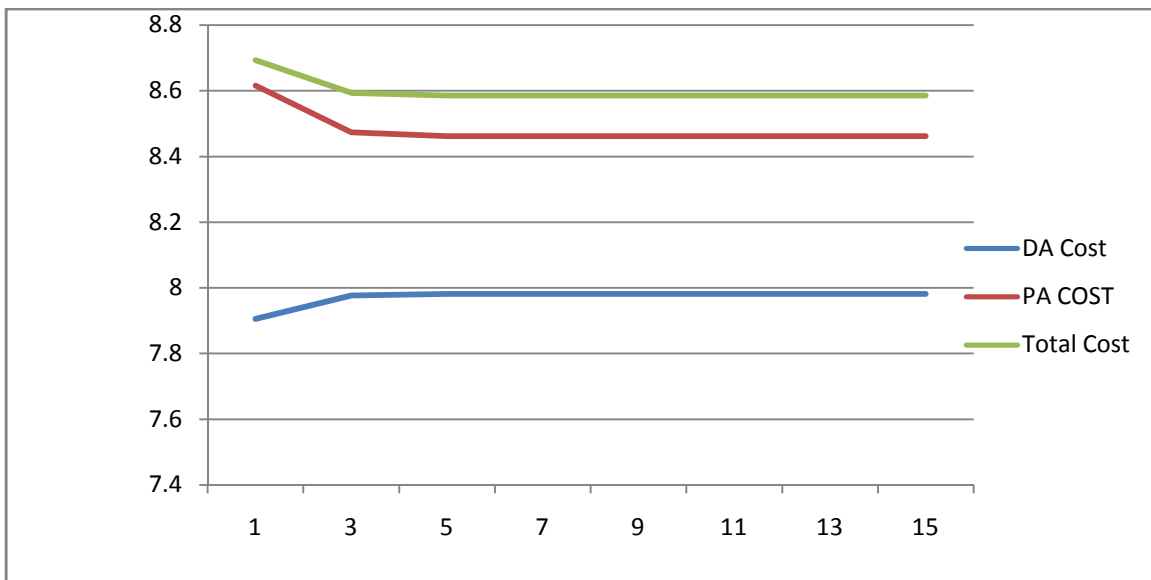


Fig. 3. Convergence Graph of Problem No.1

Modeling Carbon Footprint across Food Supply Chain

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Abstract: In the supply chain management, the environment effect is one imperative concern carbon footprint is a famous metric to evaluate an item's greenhouse gas (GHG) emissions, and help supply chain management. The focus of this paper is to assess low carbon supply chain in the food industries. So that paper optimises the carbon footprint across supply chains and also introduce indirect carbon emission concept in a network optimization model for sustainable chain management. The proposed model optimize total cost, total direct carbon emission, total indirect emission in the form of embodied carbon footprint of raw material and total trade credit amount over the purchased item in supply chain and to find a compromised solution of these objectives using multi objective goal programming.

Keywords: Low-carbon supply chain, carbon footprint, carbon emission, goal programming.

1. INTRODUCTION

Sustainable development is the main accessible and viable approach to enhance the competitiveness of a supply chain (Shaw et al., 2013). GHG emission of Sustainable production and utilization requires powerful "green" supply chain management to produce both economic and ecological advantages by minimizing waste, limiting contamination, reduction energy waste, conserving natural resources, and decreasing carbon emissions (He et al., 2016). The meaning of carbon footprint and suggested that embodied carbon footprint should represent measuring the aggregate carbon footprint of product (Shaw et al., 2013). The carbon footprint is a measure of the elite total sum of carbon dioxide outflows that is specifically and by implication brought about by an action or is collected all over the life phases of a product (Xia et al. 2013). The supply chain carbon footprint is the aggregate carbon footprint of all organizations in it (He et al. 2016). For deciding the carbon footprint of any item go along its whole life stages, the greenhouse gases emission occurs at the every stage of the life cycle like input and raw materials through manufacturing, distribution, consumer utilization (Roibas et al., 2016). Transportation is the biggest wellspring of emanations in the logistic system. Consequently, appropriate optimization of the supply chain may decrease the emission of a supply chain (Shaw et al., 2016).

2. LITERATURE REVIEW

He et al. (2016) centers to assess the effect of buyer free riding on carbon emissions in an item's life cycle over a dual channel closed loop SC and to evaluate the impact of governmental e-commerce tax on carbon emissions. . Bevilacqua et al. (2011) argue that many organizations concentrated their consideration on environmental effect of their items and use the LCA procedure to decide the carbon

footprint of various players required in a supply chain of the textile sector. Shaw et al. (2016) suggested that to constrained based green supply chain network design model show tending to carbon emissions and carbon exchanging issues. The model decides the ideal full of materials and also emissions over the SC network. Shaw et al. (2013) present indirect carbon emission and trade-credit idea in a network optimization model for sustainable supply chain. Xia et al. (2013) concentrate about on carbon footprint, production optimization theory individual enterprise and supply chain operation administration with carbon emissions constraints. A life cycle assessment model build up to evaluate the carbon footprint of the industrial production and distribution of 1 hL of lager beer in various packaging (Cimini et al., 2016). Roibas et al., (2016) aim to computed carbon footprint of Ecuadorian bananas, comprehensive of the utilization point in Spain, was 1.28 ton CO₂e per ton of banana because Bananas are most imperative food crops in the world. Van der Vorst et al. (2009) argue that food supply chain is confronted with expanded customer demands on food quality and sustainability. The extensive literature reviews were carried out for low carbon supply chain performance.

3. GOAL PROGRAMMING

Goal programming (GP) is developed and advanced by Charnes and Cooper (1997). GP is capable technique in the field of multiple decision making problem. GP is generally used to optimize the multi objective problem (Shaw et al., 2013). The overall objective function of the model is tried to minimise any deviations from specified goals (Nixon et al., 2014). In this paper is dealing with various clashing objective. Therefore, GP is good enough technique for finding a compromising solution (Shaw et al., 2012). In this paper, used goal programming is weighted goal programming to get the best compromise or satisfactory

solution of the model. A weighted goal programming can be written as

$$\text{Min } \sum_{i=1}^n (\alpha_i s_i^+ + \beta_i s_i^-)$$

Subjected to,

$$f_i(X) - s_i^+ + s_i^- = g_i, i = 1, 2, \dots, n$$

$$s_i^+, s_i^- \geq 0 \quad i = 1, 2, \dots, n$$

$X \in F$ (F is a feasible set)

Here α_i and β_i are the individual positive weights add to these deviational variables in the achievement function; $s_i^+ = \max(0, f_i(X) - g_i)$ and $s_i^- = \max(0, g_i - f_i(X))$ which are over and under achievements of the i th goal, respectively.

3.1 Model Development

Model has considered four objective functions. These objectives functions are: (i) To minimise the cost, (ii) To minimise the carbon emission, (iii) To minimise the embodied carbon footprint and (iv) To maximise the trade-credit amount over the purchasing cost. The cost and trade-credit are calculated in rupees (₹). The carbon emission and embodied carbon footprint are expressed in kilograms (kg). All the required sets and variables are shown in the following formulation.

3.1.1 Sets

I	Set of suppliers, indexed by i
J	Set of manufacturers, indexed by j
K	Set of customers, indexed by k
M	Set of different type of trucks, indexed by m
T	Set of time periods, indexed by t

3.1.2. Parameters

PC_{ijt}	Purchasing cost/material purchased (from supplier i by manufacturer j at a time period t)
ECF_{ijt}	Embodied carbon footprint of the material purchased (from supplier i by manufacturer j at time period t)
CP_{ijt}	Credit percentage over the amount of material purchased (from supplier i by manufacturer j at time period t)
$UTCSM_{ijmt}$	Transportation cost/material (from supplier i to manufacturer j using truck m at time period t)
$UTCMC_{jkmt}$	Transportation cost/material (from manufacturer j to customer k using truck

	m at time period t)
$UHCSM_{ijt}$	Holding cost/material (from supplier i to manufacturer j at time period t)
$UHCMC_{jkt}$	Holding cost/material (from manufacturer j to customer k at time period t)
$TCESM_{ijmt}$	Carbon emission in transportation/material (from supplier i to manufacturer j using truck m at time period t)
$TCEMC_{jkmt}$	Carbon emission in transportation/material (from manufacturer j to customer k using truck m at time period t)
UMC_{jt}	manufacturing cost/product (for manufacturer j at time period t)
CEM_j	Carbon emission for manufacturing/product (at manufacturer j)
S_{it}	Capacity of the supplier i at time period t
Q_{jt}	Capacity of the manufacturer j at time period t
CT_{mt}	Transportation capacity of truck m at time period t
D_{kt}	Demand of customer k at time period p

3.1.3 Decision Variables

X_{ijmt}	Transferred quantity from supplier i to manufacturer j at time period t by using truck m
Y_{jkmt}	Transferred quantity from manufacturer j to customer k at time period t by using truck m
Z_{jt}	Manufactured quantity by manufacturer j at time period t

3.1.4 Deviation variables

$\square_a^-, s_a^+$	Under achievement and overachievement from total cost of supply chain goal/target, respectively
s_b^-, s_b^+	Under achievement and overachievement from carbon emission goal/target, respectively
s_c^-, s_c^+	Under achievement and overachievement from embodied carbon footprint goal/target, respectively
s_d^-, s_d^+	Under achievement and overachievement from trade credit goal/target, respectively

3.1.5 Model

The objective of GP model is to minimise the deviations from the goals/targets. Objective function (1) minimizes the weighted deviations around the goals/targets. In this

equation, s_a^+, s_b^+, s_c^+ and s_d^- are the deviational variables of cost, carbon emission, embodied carbon footprint and trade credit goals, respectively, and $\alpha_a, \alpha_b, \alpha_c$ and β_d are the corresponding weights of the above deviations of goals.

$$\text{Minimize} = \alpha_a s_a^+ + \alpha_b s_b^+ + \alpha_c s_c^+ + \beta_d s_d^- \quad (1)$$

$$\text{Total cost goal (A) = Total purchasing cost + Total transportation cost + Total handling cost + Total Production cost} + s_a^- + s_a^+ \quad (2)$$

where

$$\text{Total purchasing cost} = \sum_{i=I} \sum_{j=J} \sum_{t=T} P C_{ijt} \sum_{m=M} X_{ijmt} \quad (3)$$

$$\begin{aligned} \text{Total transportation cost} &= \sum_{i=I} \sum_{j=J} \sum_{m=M} \sum_{t=T} X_{ijmt} U T C S M_{ijmt} \\ &+ \sum_{i=I} \sum_{j=J} \sum_{m=M} \sum_{t=T} Y_{jkm t} U T C M C_{jkm t} \end{aligned} \quad (4)$$

Total handling cost =

$$\begin{aligned} &\sum_{i=I} \sum_{j=J} \sum_{t=T} U H C S M_{ijt} \sum_{m=M} X_{ijmt} \\ &+ \sum_{j=J} \sum_{k=K} \sum_{t=T} U H C M C_{jkt} \sum_{m=M} Y_{jkm t} \end{aligned} \quad (5)$$

$$\text{Total production cost} = \sum_{j=J} \sum_{t=T} Z_{jt} U M C_{jt} \quad (6)$$

Total carbon emission goal (B) = Emission for transporting the material from suppliers to

$$\text{Manufacturers + Emission for transporting the material from Manufacturers to customers + Manufacturing carbon emission} + s_b^- - s_b^+ \quad (7)$$

Where

Emission for transporting the material from suppliers to manufacturers

$$= \sum_{i=I} \sum_{j=J} \sum_{m=M} \sum_{t=T} X_{ijmt} T C E S M_{ijmt} \quad (8)$$

Emission for transporting the material from manufacturers to customers

$$= \sum_{j=J} \sum_{k=K} \sum_{m=M} \sum_{t=T} Y_{jkm t} T C E M C_{jkm t} \quad (9)$$

Manufacturing carbon emission

$$= \sum_{j=J} C E M_j \sum_{t=T} Z_{jt} \quad (10)$$

Total embodied carbon footprint goal (C)

$$= \sum_{i=I} \sum_{j=J} \sum_{t=T} E C F_{ijt} \sum_{m=M} X_{ijmt} + s_c^- - s_c^+ \quad (11)$$

Trade credit goal (D)

$$= \sum_{i=I} \sum_{j=J} \sum_{t=T} P C_{ijt} C P_{ijt} \sum_{m=M} X_{ijmt} + s_d^- - s_d^+ \quad (12)$$

All the constraints of the model are illustrated in (13)–(22).

$$\sum_{j=J} \sum_{m=M} X_{ijmt} \leq S_{it} \quad \forall i \in I, t \in T \quad (13)$$

$$\sum_{k=K} \sum_{m=M} Y_{jkm t} \leq Q_{jt} \quad \forall j \in J, t \in T \quad (14)$$

$$\sum_{i=I} \sum_{j=J} X_{ijmt} \leq C T_{mt} \quad \forall m \in M, t \in T \quad (15)$$

$$\sum_{j=J} \sum_{k=K} Y_{jkm t} \leq C T_{mt} \quad \forall m \in M, t \in T \quad (16)$$

$$\begin{aligned} \sum_{i=I} \sum_{m=M} X_{ijmt} - \sum_{k=K} \sum_{m=M} Y_{jkm t} &= 0 \\ \forall j \in J, t \in T \end{aligned} \quad (17)$$

$$\sum_{i=I} \sum_{m=M} X_{ijmt} - Z_{jt} = 0 \quad \forall j \in J, t \in T \quad (18)$$

$$Z_{jt} \leq Q_{jt} \quad \forall j \in J, t \in T \quad (19)$$

$$\sum_{i=I} \sum_{m=M} Y_{jkm t} \geq D_{kt} \quad \forall k \in K, t \in T \quad (20)$$

$$X_{ijmt}, Y_{jkm t}, Z_{jt} \geq 0 \text{ and integer}$$

$$\forall i \in I, j \in J, k \in K, m \in M, t \in T \quad (21)$$

$$s_a^+, s_b^+, s_c^+, s_d^+, s_a^-, s_b^-, s_c^-, s_d^- \geq 0 \quad (22)$$

4. APPLICATION ON CASE ORGANIZATIONS

The proposed model is explained on a case study of food supply chain. X is a food manufacturing company. The

study considers that X Company has three manufacturing plants in India. All the three manufacturing plants sources raw ingredients from three reliable suppliers. For optimising the SC realistic value have taken. For solving

the model the data sets are shown in Table 1-14. Model has taken, I=3, J=3, K=3, M=3 and T=3 for explaining the case study.

TABLE 1: Costs (₹) of the raw material purchased from different suppliers at different time period.

			Supplier 1			Supplier 2			Supplier 3		
Period			1	2	3	1	2	3	1	2	3
Manufacturer	1		3	4	4	5	6	4	3	5	6
	2		4	6	5	4	7	6	4	7	7
	3		6	8	7	7	8	8	6	7	8

TABLE 2: Trade credit percentage (%) over the purchased amounts at different periods.

			Supplier 1			Supplier 2			Supplier 3		
Period			1	2	3	1	2	3	1	2	3
Manufacturer	1		14	7	19	0	6	4	10	19	13
	2		9	0	11	7	3	14	0	0	7
	3		24	9	17	14	0	9	9	7	19

TABLE 3: Embodied carbon footprints ($\times \frac{1}{10^2}$ kg) of raw material purchased from suppliers at different time period.

			Supplier 1			Supplier 2			Supplier 3		
Period			1	2	3	1	2	3	1	2	3
Manufacturer	1		2.3	2.6	2.7	1.8	1.9	2.1	1.4	1.7	2
	2		2.3	2.6	2.7	1.8	1.9	2.1	1.4	1.7	2
	3		2.3	2.6	2.7	1.8	1.9	2.1	1.4	1.7	2

TABLE 4: Raw material handling Costs (₹) from suppliers to manufacturers at different period.

			Supplier 1			Supplier 2			Supplier 3		
Period			1	2	3	1	2	3	1	2	3
Manufacturer	1		0.009	0.009	0.019	0.014	0.019	0.009	0.014	0.012	0.01
	2		0.019	0.01	0.013	0.019	0.011	0.012	0.01	0.012	0.011
	3		0.008	0.007	0.009	0.007	0.01	0.019	0.01	0.011	0.012

TABLE 5: Finished product handling Costs (₹) from manufacturers to customers at different period.

			Manufacturer 1			Manufacturer 2			Manufacturer 3		
Period			1	2	3	1	2	3	1	2	3
Customer	1		0.008	0.009	0.012	0.014	0.019	0.01	0.013	0.012	0.01
	2		0.014	0.01	0.013	0.019	0.011	0.012	0.011	0.019	0.011
	3		0.009	0.014	0.019	0.007	0.01	0.019	0.01	0.011	0.012

TABLE 6: Raw material transportation cost (□) from suppliers to manufacturers by different trucks at different periods.

					Supplier 1			Supplier 2			Supplier 3		
Period					1	2	3	1	2	3	1	2	3
Manufacturer	1	Truck	1		0.3	0.3	0.3	0.2	0.3	0.3	0.4	0.3	0.3
				2	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.4	0.4
				3	0.5	0.5	0.5	0.4	0.5	0.5	0.6	0.5	0.5
	2	Truck	1		0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.3
				2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	3	Truck	1		0.2	0.2	0.4	0.2	0.2	0.4	0.2	0.2	0.4
				2	0.3	0.3	0.5	0.3	0.3	0.5	0.3	0.3	0.5
				3	0.5	0.5	0.6	0.5	0.5	0.6	0.5	0.5	0.6

TABLE 7: Finished product transportation cost (□) from manufacturers to customers by different trucks at different periods.

					Manufacturer 1			Manufacturer 2			Manufacturer 3		
Period					1	2	3	1	2	3	1	2	3
Customer	1	Truck	1		0.2	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.4
				2	0.3	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.5
				3	0.4	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.6
	2	Truck	1		0.4	0.4	0.3	0.4	0.4	0.3	0.3	0.4	0.3
				2	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5
				3	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.6	0.6
	3	Truck	1		0.2	0.2	0.4	0.2	0.2	0.3	0.2	0.2	0.4
				2	0.3	0.3	0.5	0.3	0.3	0.4	0.3	0.3	0.5
				3	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6

TABLE 8: Emission ($\times \frac{1}{10^3}$ kg) for raw material transportation from suppliers to manufacturers by different trucks at different periods.

					Supplier 1			Supplier 2			Supplier 3		
Period					1	2	3	1	2	3	1	2	3
Manufacturer	1	Truck	1		90	90	90	140	140	140	190	190	190
				2	70	70	70	80	80	80	140	140	140
				3	30	30	30	50	50	50	90	90	90
	2	Truck	1		290	290	290	60	60	60	290	290	290
				2	240	240	240	30	30	30	240	240	240
				3	140	140	140	10	10	10	210	210	210
	3	Truck	1		80	80	80	50	50	50	90	90	90
				2	60	60	60	30	30	30	60	60	60
				3	40	40	40	10	10	10	30	30	30

TABLE 9: Emission ($\times \frac{1}{10^3}$ kg) for finished product transportation from manufacturers to customers by different trucks at different periods.

					Manufacturer 1			Manufacturer 2			Manufacturer 3		
Period					1	2	3	1	2	3	1	2	3
Customer	1	Truck	1		290	290	290	190	190	190	270	270	270
			2		240	240	240	140	140	140	190	190	190
			3		110	110	110	90	90	90	100	100	100
	2	Truck	1		60	60	60	80	80	80	50	50	50
			2		40	40	40	60	60	60	30	30	30
			3		20	20	20	40	40	40	10	10	10
	3	Truck	1		140	140	140	100	100	100	130	130	130
			2		110	110	110	80	80	80	100	100	100
			3		80	80	80	50	50	50	70	70	70

TABLE 10: Product manufacturing cost (□) at different periods.

		Manufacturer 1		Manufacturer 2		Manufacturer 3	
Period	1	2.4		3.9		1.9	
	2	2.9		3.4		3.9	
	3	3.9		2.4		4.9	

TABLE 11: Capacities of the suppliers at different periods.

		Supplier 1		Supplier 2		Supplier 3	
Period	1	12400		11900		10900	
	2	9900		12900		11900	
	3	11900		11900		12400	

TABLE 12: Capacities of the manufacturers at different periods.

		Manufacturer 1		Manufacturer 2		Manufacturer 3	
Period	1	13100		12400		11400	
	2	10400		13400		11900	
	3	11900		12400		12400	

TABLE 13: Demands of the customers at different periods.

		Customer 1		Customer 2		Customer 3	
Period	1	8400		8600		8500	
	2	8900		7900		8400	
	3	7400		8400		8900	

TABLE 14: Trucks' capacities for each echelon at different periods.

		Period 1		Period 2		Period 3	
Truck	1	34500		34500		34500	
	2	35500		35500		35500	
	3	36500		36500		36500	

Model has the following goals/targets. The goals are cost (A) = ₹633161.4, carbon emission (B) = 96, 150 kg, embodied carbon footprint (C) = 1, 395.4 kg and trade credit (D) = ₹81778. The main focus of model is to minimise the carbon emission and embodied carbon footprint in SC. The first priority of model is to minimise carbon emission and second priority is to minimise the embodied carbon footprint. To achieve these, the following weights have chosen ($\alpha_a = 0.1$, $\alpha_b = 0.4$, $\alpha_c = 0.3$ and $\beta_d = 0.2$) for the deviations of the following goals A, B, C and D, respectively. The model considers that the carbon emission per food product produced in manufacturing plant 1, 2 and 3 is 1.4, 1.1 and 1.3 kg, respectively.

Microsoft Excel 2010 software has used for solving the model. Study found a compromised solution of the model after solving this model in Microsoft Excel 2010 that is represented by Case 1, as show in Table 15. After

running/solving the model, a deviation of ₹31329.9 from total cost goal is found. The positive deviation is 4.94% from the total cost goal. Table 15 shows all the deviational value from the goal. The deviations are 12.40%, 14.02% and 36.46% from the carbon emission (B), embodied carbon footprint (C) and trade credit goal (D), respectively.

If more weights is given on carbon emission and embodied carbon footprint, than found that maximum number of material/product are transported by Truck 3, because Truck 3 emits lesser CO₂ in comparison to other trucks. If the cost at priority in the model then in this case Truck 1 is used for transportation of material/product because of its lower transportation cost other than two trucks. From the solution Table 15 shows that Truck 2 has moderate emission and transportation cost/rental fees. And it shows the mixed behavior of the assignment of truck.

TABLE 15: Solution of the case studies and comparison among the different solutions.

Case 1 ($\alpha_a = 0.1$, $\alpha_b = 0.4$, $\alpha_c = 0.3$, $\beta_d = 0.2$)				Case 2 ($\alpha_a = 0.4$, $\alpha_b = 0.3$, $\alpha_c = 0.2$, $\beta_d = 0.1$)				Individually optimized objective function
s_a^+	31329.9	Y_{1133}	3900	s_a^+	1143.7	Y_{1113}	3900	Total cost = ₹633164.4
s_b^+	11925	Y_{1213}	8000	s_b^+	20691	Y_{1213}	8000	Total carbon
s_c^+	195.7	Y_{2311}	2200	s_c^+	214.5	Y_{2311}	2200	emission = 96150 kg
s_d^-	29822	Y_{2132}	5000	s_d^-	46001	Y_{2112}	8900	Total embodied carbon
X_{1131}	1000	Y_{2312}	8400	X_{1111}	2200	Y_{2312}	4500	footprint = 1395.4 Kg
X_{1311}	11400	Y_{2133}	3500	X_{1311}	10200	Y_{2113}	3500	Total trade
X_{1232}	9900	Y_{2313}	8900	X_{1112}	9400	Y_{2313}	8900	credit = ₹81778
X_{1133}	11400	Y_{3211}	8600	X_{1212}	500	Y_{3211}	8600	
X_{1233}	500	Y_{3321}	2800	X_{1213}	11900	Y_{3311}	1600	
X_{2221}	2200	Y_{3132}	1400	X_{2211}	2200	Y_{3312}	1400	
X_{2222}	3500	Y_{3213}	400	X_{2212}	12900	Y_{3213}	400	
X_{2213}	11900	Z_{11}	11900	X_{2113}	11900	Z_{11}	13100	
X_{3131}	10900	Z_{12}	10400	X_{3111}	10900	Z_{12}	10400	
X_{3132}	10400	Z_{13}	11900	X_{3112}	1000	Z_{13}	11900	
X_{3322}	1400	Z_{21}	2200	X_{3312}	1400	Z_{21}	2200	
X_{3133}	500	Z_{22}	13400	X_{3213}	500	Z_{22}	13400	
X_{3333}	400	Z_{23}	12400	X_{3313}	400	Z_{23}	12400	
Y_{1131}	8400	Z_{31}	11400	Y_{1111}	8400	Z_{31}	10200	
Y_{1321}	3500	Z_{32}	1400	Y_{1311}	4700	Z_{32}	1400	
Y_{1132}	2500	Z_{33}	400	Y_{1212}	7900	Z_{33}	400	
Y_{1212}	7900			Y_{1312}	2500			

5. CONCLUSIONS

In this paper, the study has suggested a SC optimisation model by considering the sustainability issues. The model gives many insights in the management of sustainable supply chain. Multi objective GP has been used to handle numerous conflicting goals such as cost, carbon emission, embodied carbon footprint and trade credit. A compromised solution at satisfactory level can be achieved by solving the model. The suggested model quantifies the total cost, total carbon emission, embodied carbon footprint (indirect carbon emission) and trade credit in a SC by taking different types of trucks having different emission level. This model also provides information when to use a particular truck for the transportation of material in the SC.

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Impact of Supply Chain Strategy Dimensions on Supply Chain Performance Dimensions: An Empirical study in the Indian Automotive Industry

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Abstract: Despite the intensive research has been done in supply chain management (SCM) a little research has been done so far on this issue with respect to a single sector in India. This research in the field of Supply Chain Management is mainly concentrate on the impact of supply chain strategy (SCS) dimensions on Supply chain performance (SCP) in the supply chain .This research bridges the gap and deficiency on the research done previously in this issue and particularly about the Impact of Supply Chain Strategy on Supply Chain Performance. Hence, the main objective of this study is to find the influence of supply chain Strategies (SCS) on SCP. Furthermore, enhanced supply chain Strategies is directly related to improve supply chain performance. This research is based on Indian Automobile Industry which is the fasted growing and major contributor in GDP in India. The research find the Impact of Supply Chain Strategy on Supply Chain Performance based on their results, Fantasy et al. (2009) In his research he suggested that further investigating his research in a different geographical region. To widen understanding on this topic and to go after the recommendation of the preceding research, this research closely related to Fantasy et al. (2009) and this research done in the Indian automotive industries.

Keywords: Supply Chain Strategy (SCS), Supply Chain Performance (SCP)

1. INTRODUCTION

The economic growth of India which is developing country is typically dependent on its key industry and is key resources .The automobile industry in India in recent decade shown a momentous growth and established to be one of the one of the fastest growing and one of the strongest drivers of technology. Growth which generate employment (Gottschalk and Kalmbach, 2007). The new & emerging trends opens a new era in automobile industry for developing country like India (Choudhary and Goyal, 1997) after economic globalization the Indian automobile industry has got a remarkable market potential. Globalization creates a tremendous development in the field of technology especially in communications and transport. After 1991 due economical liberalization the GOI has made tremendous changes in economic policy which gives enormous opportunities for FDI to investments in the country. Post globalization the automobile industry in developing countries is experiencing a rapid transformation has made remarkable impacts on Indian economy. The automobile sector is one of the largest in the world. The industry accounts for 7.1 per cent of the country's Gross Domestic

Product (GDP). The Two Wheelers segment with about 81 per cent market share is the leader of the Indian automobile market owing to a growing middle class and a young population. Moreover, the increasing interest of the companies in the rural markets further aided the growth of the sector. The overall Passenger Vehicle (PV) segment has around 13 per cent market share.

From previous research it is clear that there is a definite correlation between implementation of effective and efficient Supply Chain Management (SCM) practices like Supply Chain Strategy and Supply chain Flexibility (Souresh Bhattacharya, Sunil Giri et al.2014) .Due to this the automotive industry in Indian is facing an interesting evolutionary phase and the automotive supply chain has a big role to play in this evolution. The supply chain strategy dimension like effective supply chain strategy, Customer satisfaction and minimization of cost connected with supply chain is the most important aspect for automobile industry. The most crucial aspect of this value chain is the complex system of SCM which incorporated with manufacturing .These vital dimensions of SCM (Strategy, Flexibility & performance) will provide free hand to business executive

to take decisions on SCM .With today's cutthroat competition and scarcity of resources the firm's must be optimal utilized to understand better application of SCM and thereby offer better value to customers and improve the performance of the organization (Chow et al., 2006). Currently Automobile industry in our country facing a challenge counterpart its supply chain standards with developed countries (Chang-Tai, H. et al 2009) and industry having a tremendous potential for integration of supply chains (Park, D.et al 2012) .The Indian automobile industry requires sustainable growth because its significant contribution towards GDP. The industry will developed a supply chain that can manage long term growth along with flexibility and much responsive which can handle any short term volatility. The industry on the stage of rapid changes in due to shorter product life cycle, new customers, product customization .This research is based on impact of major dimensions of supply chain strategy on the supply chain performance

2. LITERATURE REVIEW

Today's competitive market require effective and efficient supply chain strategies which are essential to construct competitiveness and make their position in the market so that companies can compete their competitors. Along with business strategies companies must think seriously supply chain strategy which is can build companies's position in competitive market.

Supply chain strategy is different for different product. Due to unique features of product companies requires definite supply chain strategies for that product. Companies can make their strategy as per supply and demand uncertainty, product life cycle and manufacturing complexity Due to these uncertainties diverse supply chain strategies emerged (H.L.Lee, 2002).Hence it is necessary that companies adopt the accurate SC strategy so that they can compete in the market. For taking leverage over competitors companies adopt customer oriented strategies such as customized logistics and agility which enhanced the demand while operational strategies and lean network enhanced supply side capabilities (E. A. Morash 2001) .Supply chain performance is a crucial and quickly developing area for researcher in supply chain management in current scenario. To conquer an efficient and effective supply chain, many

companies have realized the implication of performance evaluation and what measures should be used. The main goal of performance measurement are to improve the efficiency and effectiveness of a supply chain (Beamon 1999; Gunasekaran et al. 2001).The organizational performance refers to how well an organization acquire its market -oriented, financial goals in terms of performance items such as return on assets(ROA), market share and growth rate(Vickery et al. 1991). In supply chain performance cost, quality, response time and service quality level are the performance indicators (Christopher and Towill, 2001). Lippman (2001) recognized the effect of product cycle time, due date performance, cost and quality on operational performance.

The evaluate firm performance has been by in different manner by different researchers to assist firm in measuring their supply chain. There is number of problems in measurement of firm's performance (Richey et al. 2009). Firm performance include three different types of measurement for performance these are resources measurement, output measurement, and flexibility (Sukati et al. 2012).Recently supply chain performance is becoming area of research for many researcher. Reputed industries are trying to hard and finds the ways which can enhance performance of supply chain so that the can efficiently controlling their business activities.Companies concerned for their competition because market is shifting from individual company performance to supply chain performance. The whole chain's can be able to fulfill the end-customer's needs through product availability and responsive, on-time delivery.Traditional company boundaries are changing as companies find out new ways of working together to achieve the ultimate supply chain goal along with the ability to fill customer orders faster and more efficiently than the competition..

3. HYPOTHESES AND RESEARCH MODEL

This research find the impact of supply chain management strategy on supply chain performance which is based on the Canadian researchers.Which developed a model which show the theoretical relationship among, strategy, flexibility and performance. Figure 1 is simplified to show strategy performance connections in accordance with the suggested hypotheses by Fantazy *et al.* (2009).

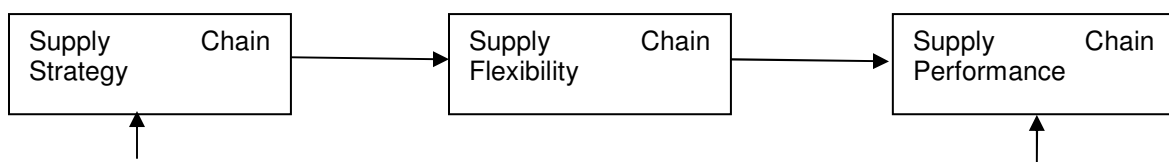


Fig. 1. Basic Model (Fantazy et al. 2009)

Based on the research model Fantazy *et al.* (2009) in this research following hypotheses developed.

H1: Supply chain strategy have direct impact on the supply chain performance Dimensions.

H2: Deals with impact of adoption of proper Supply Chain Strategy on Supply Chain Performance.

H3: The overall total and indirect effects of Supply Chain Strategy on Supply Chain Performance

Research Model

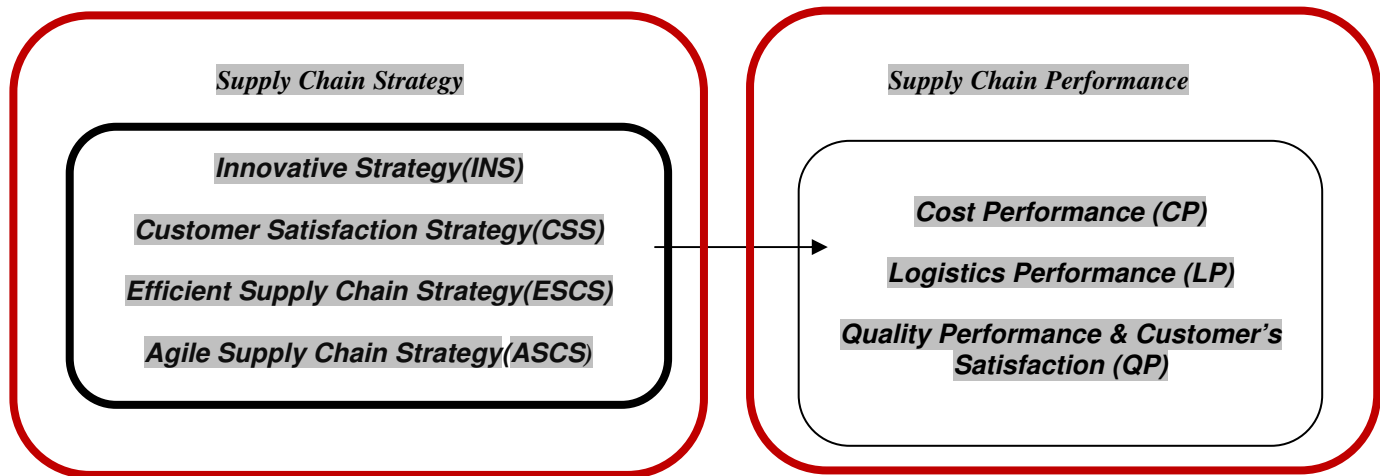


Fig. 2. Research Model

4. RESEARCH METHODOLOGY

4.1 SAMPLING AND DATA COLLECTION

The data is collected from different methods that can be used for collecting data viz. using a survey strategy, such as structured observation, interviews and questionnaires (Saunders et al. 2007). In statistically testing the enormous amount of structured data needed from different respondent who fill the questionnaire. Hence large number of respondents that therefore should be contacted and the small information available from respondents, the questionnaire is selected to collect the data needed to test the above hypotheses (Cooper and Schindler 2003; Saunders et al. 2007). Besides this (Cooper and Schindler 2003)

- A questionnaire allows get in touch inaccessible contacts
- It is less costly (it costs less time and money to reach a large sample)
- A questionnaire is perceived as more unspecified
- It allows respondents to take time to think about the questions
- The data can easy be worked out used for analyzing and testing

Although a questionnaire is the most common choice to collect the data needed in this thesis, it has also some disadvantages

- No interviewer interference available for explanation;
- The questionnaire may not be too long, so the measurement items are limited;

This research is based on a quantitative approach, which was conducted on Indian automobile industries the data collection instrument used was a questionnaire which was sent to small and medium-sized automobile industries and ancillary industries within different supply chains. The data from 129 respondents are also classified by their job functions are corporate executive, purchasing, manufacturing/production, distribution/logistic, SCM, transportation, material, and operation from Indian automobile industries

4.2 RELIABILITY ANALYSIS

The Cronbach's alpha was conducted to assess the reliability of each item. Cronbach Alpha values over 0.7 indicate that all the date can be considered consistent (Nunally, 1978). For each of the item, factor analysis was used to reduce the total number of dimensions to controllable factor. Principal components analysis is used to extract factors with (eignevalue greater than 1) Varimax rotation is used for factor matrix. Sampling adequacy measurement tests are also examined via the Kaiser-Meyer-Olkin statistics to validate use of factor analysis.

Factors analysis showed that the KMO value of 0.81 indicate sampling adequacy. Factors analysis showed that the KMO value of 0.81 indicate sampling adequacy. The factor model for supply chain strategy indicates four distinct factors loading without any misclassification: innovative strategy (INS), customer satisfaction strategy (CSS), efficient supply chain strategy (ESCS), and agile supply chain strategy (ASCS). Cronbach's alphas among 14

items in the questionnaires exceeded 0.7. Four items are identified for innovative strategy (INS), four items identified for customer satisfaction strategy (CSS), two items are identified for efficient supply chain strategy (ESCS), and four items are identified for agile supply chain strategy (ASCS). These items are treated as independent variables. A similar factor analysis was applied to the supply chain Performance practices areas: cost performance (CP), logistic performance (LP) and customer satisfaction performance (CS). A total of 16 items were reduced to three factors loadings. Cronbach's alphas among 16 items in the

questionnaires are exceeded 0.7. Seven items are identified for: cost performance (CP), four items identified for logistic performance (LP) and five items are identified for customer satisfaction performance (CS). These items are treated as dependent variables. The KMO value of 0.78 indicate sampling adequacy

4.3 CORRELATION ANALYSIS

The correlation between independent variables (supply chain strategy) and dependent variables (supply chain performance) were shown in table 1

TABLE 1: Correlation Analysis

	Inovative Strategy	Customer Satisfaction Strategy	Efficient Supply Chain Strategy	Agile Supply Chain Strategy	Cost Performance	Logistic Performance	Quality Performance
Inovative Strategy	1						
Customer Satisfaction Strategy	.521**	1					
Efficient Supply Chain Strategy	.033	.244*	1				
Agile Supply Chain Strategy	-.049	.135	.651**	1			
Cost Performance	.117	.162	.431**	.462**	1		
Logistic Performance	-.133	.081	.326**	.564**	.567**	1	
Quality Performance	-.166	.218	.152	.518**	.292*	.499**	1

*p value <0.05, **p value <0.01

Result show that Innovative Strategy & Customer satisfaction strategy had no significant correlation with all three supply chain performance parameters but Efficient supply chain strategy had positive correlation with cost performance and logistic performance but it had no correlation with quality performance .Agile supply chain strategy had positive correlation with all three parameters of supply chain performance

4.4 REGRESSION ANALYSIS

The parameters of this model are estimated using multivariate regression analysis. Table 1 shows coefficients of each model along with corresponding test statistics. In Model 1 where the dependent variable is cost performance, the model seem to be reliable (p-value for F<0.01 and adjusted R-square of 0.259. Model 2, dependent variable is logistic performance. The model also seem to be reliable (p-value for F<0.01 and adjusted R-square of 0.581. Model 3, dependent variable is quality performance. Once again, the model also seem to be reliable (p-value for F<0.01), and adjusted R-square of 0.442.

TABLE 2: Model parameter estimates of supply chain orientation (t- Value in parenthesis)

	Model 1 Dependent variable = Cost performance (CP)	Model 2 Dependent variable = Logistic Performance(LP)	Model 3 Dependent variable = Customer Satisfaction (CS)
Constant	1.582	2.714	3.034
Innovative Strategy(INS)	0.156	-0.179	-0.372

	Model 1 Dependent variable = Cost performance (CP)	Model 2 Dependent variable = Logistic Performance(LP)	Model 3 Dependent variable = Customer Satisfaction (CS)
	(0.964)	(-1.238)	(-2.802)
Customer Satisfaction Strategy(CSS)	.000 (-0.002)	0.086 (0.794)	0.328 (3.281)
Efficient Supply Chain Strategy(ESCS)	0.148 (1.407)	-0.054 (-0.569)	-0.259 (-2.992)
Agile Supply Chain Strategy(ASCS)	0.300 (2.256)	0.510 (4.281)	0.604 (5.514)
Adj R²	0.259	0.581	0.442
F-Value	5.241	7.650	11.881

*p value <0.05, **p value <0.01

5. RESULTS

In current research, the following outcomes were obtained: The correlation analysis showed that innovative strategy is not related to supply chain performance parameters, while customer satisfaction strategy has very weak positive correlation with supply chain performance parameters. Agile supply chain strategy is significantly correlated related to supply chain cost performance and having weak correlation with logistic performance and customer satisfaction performance. Agile supply chain strategy significantly correlated to all supply chain performance. Finding show there is a weak relationship between supply chain management strategy and supply chain performance. Hypothesis 1 examine the impact of supply chain management strategy and supply chain performance and testing found that there is a little impact between supply chain management strategy and supply chain performance. Hypothesis 2 considered the adoption of proper strategy can improve supply chain performance. According to the result shown proper adoption of strategy effect supply chain performance. Hypothesis 3 show the overall impact of supply chain strategy results show that supply chain strategy effect on cost performance is less than that of logistic performance and customer satisfaction performance.

6. DISCUSSION AND IMPLICATIONS

The most important issue faced by organizations is identified and apply the best strategy to organizational practices. Research conclusion show that supply chain management strategy is the weak relationship to supply chain performance. Supply chain management strategy is key factors and being impact on supply chain performance. To efficiently managing the supply chain organizations need to agree to proper supply chain strategies into supply management chain practices (Sufian, 2010). Efficient supply chain management is vital aspect to building and sustaining competitive advantage in the market place. The

research hypotheses are tested by using multiple regression models. The result of this study may be contributes to the supply chain management knowledge in several ways. This study was to put in to the knowledge on supply chain management performance by finding the impact of supply chain management strategy & supply chain management performance.

7. LIMITATION AND FUTURE RESEARCH

There are a number of limitations of current research..

- This study limited only on automobile industry in India. From single-sector study is that the conclusions may not be generalizable to other sectors..
- The sample choice and size was based on a convenience sample, which is often used for exploratory work (Zikmund, 2003), rather than a random probability sample.
- The sample represented a limited number of companies in one sector only.
- The study is based on a questionnaire. Therefore, there is a possibility of respondents answering questions in their own opinion.

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Validating Remanufacturing Framework for Organizational Performance in an Indian Industry

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Abstract: Remanufacturing is the process of converting used and discarded products/ components/parts of equipment into the same as new condition. The aim of this paper is to develop an instrument and find the effect of critical success factors on performance measures for establishing remanufacturing. The effect of critical success factors on performance measures was giving the awareness for successful achievement of establishing the remanufacturing industry. This effect was supporting growth and achievement for remanufacturing industry. Based on an exploratory study of Indian organizations, remanufacturing factors and performance measures factors have been identified. This paper discussed the results of a survey on performance factors of the feasibility of remanufacturing in Indian manufacturing industries. The validation of this developed instrument through an artificial neural network.

Keywords: Critical Success Factors, Performance Measure Factors, ANN.

1. INTRODUCTION

The sustainable development has to save resources and improve the environment. Many industries across the world are engaged in a remanufacturing process to improve their performance improvement. The “6R” rule is the important to measure the goal. 6R rule consists of Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture. Remanufacturing is one of the most active factors in “6R” rule. In remanufacturing, the parts are disassembled, cleaned and assessed for wear and breakage. Worn out, missing or not- functioning components are replaced with new components. The remanufacturing process takes place in a factory environment. It is organized as an industrial process so that it can benefit from the advantage of a series of production. These are a constant quality level and rationalization. Remanufacturing is the process of renovation used products makes sure that the quality of remanufactured products is equivalent to new products. Remanufacturing is the process of value recovery and reuse of used products. It has been accepted by the western world. Now, India is to take up as an organized industrial sector. The remanufacturing component is indicated 65% of the energy saved in the manufacture of the original product and preserved for the remanufactured product. These are energy and raw materials savings, economic contribution per unit of product; products are remanufactured and kept out of the waste stream longer. Landfill space perseveres, air pollution is reduced.

2. LITERATURE REVIEW

Winifred L. Ijomah *et al.*(1999) have described the remanufacturing evidence of environmentally conscious business practice in the U.K. Surendra M. Gupta and Hasan K. Aksoy (1999) explained an analytical model for remanufacturing systems. Geraldo Ferrer and Robert U. Ayres (2000) were suggested the impact of remanufacturing in the economy. Anstine J. (2000) has described the consumer’s willingness to pay for recycled content in plastic kitchen garbage bags as a hedonic price approach. Ali Rıza Motorcu and Abdul kadir Gullu (2006) were analyzed a statistical process control in machining, a case study for machine tool capability and process capability. Atul B. Borade and Satish V. Bansod (2007) were studied the domain of supply chain management. Bei L.T.and E.M.Simpsons (1995) has determined consumer purchase decision for recycled products. Bert Bras and Rick Hammond (1996) were described towards design for remanufacturing metrics for assessing re-manufacturability. Barr S, A Gilg (2001) was analyzed the factors influencing environmental attitudes and behaviors. B. Mahadevan *et al.* (2003) have reviewed the Periodic review, push inventory policies for remanufacturing. Barr S. (2007) was identified the factors influencing environmental attitudes and behaviors. Charles L. Goldey *et al.* (2004) were used remanufactured switching equipment to reduce restoration time in case of a disaster. Christos Zikopoulos and George Tagaras (2008) were investigated the attractiveness of sorting before disassembly in remanufacturing. Dewhurst P.

(1993) was designed the product for manufacture and disassembly. Donald and Lyons (2005) were analyzed the integrating waste, manufacturing, and industrial symbiosis. Kampan Mukherjee and Sandeep Mondal (2010) were analyzed some issues related to remanufacturing technology a case of an Indian company. Lund, Robert T., and Hauser, William M. (2010) studied on remanufacturing an American perspective. In (2011) an article published on remanufacturing in the automotive industry: challenges and limitations. In (2012) an article published on remanufacturing an answer to global warming. Henry Widera and Gunther Seliger (2015) have described the methodology for exploiting potentials of remanufacturing by reducing complexity for original equipment manufacturers. Rui Zhanga *et al.* (2015) have described a simulation based genetic algorithm approach for remanufacturing process planning and scheduling. Anjar Priyono, et.al (2015) has discussed the strategic operations framework for disassembly in remanufacturing. Sara J. Ridley and WL Ijomah (2015) have developed a novel pre-processing inspection methodology to enhance productivity in automotive product remanufacture. Ian Graham *et al.* (2015) have described the performance measurement and KPIs for remanufacturing. Euan Long *et al.* (2016) have analyzed the technical solutions to improve global sustainable management of waste electrical and electronic equipment (WEEE) in the EU and China. Harpreet Singh and Pramod Kumar Jain (2016) have concluded that remanufacturing of functional surfaces using developed ECH machine. Factors affecting for remanufacturing are

IF1- Top management involvement and commitment, IF2- Human resource management, IF3- Remanufacturing support system, IF4- Forward/reverse logistics system design, IF5- Remanufacturing process, IF6- Suppliers involvement for remanufacturing, IF7- Sustainable development practices. The literature review indicates wide variations in approach and definition of organization performance measures.

3. RESEARCH METHODOLOGY

This research paper is to identify and interpret the critical factors that affect remanufacturing and organizational performance and statistically validate if any correlation exists between them. The instrument developed for collecting the data contains 56 variables; twenty-two for remanufacturing process, eight for remanufacturing support system, six for sustainable development practices, six for forward/reverse logistics, six for human resource management, four for suppliers involvement and four for management. Figure 1 represents the test model that has been proposed for an Indian remanufacturing industry. To test the causal relationship multiple regression analysis was carried out. The main reason for employing multiple regressions is to determine the minimum number of a set of variables, which are most strongly related to the dependent variable and to estimate the percentage of variations in the dependent variable. The sample was collected from different industries. The continuous efforts by the authors and the support of the study organizations generated a 49.2% response rate, which was quite encouraging.

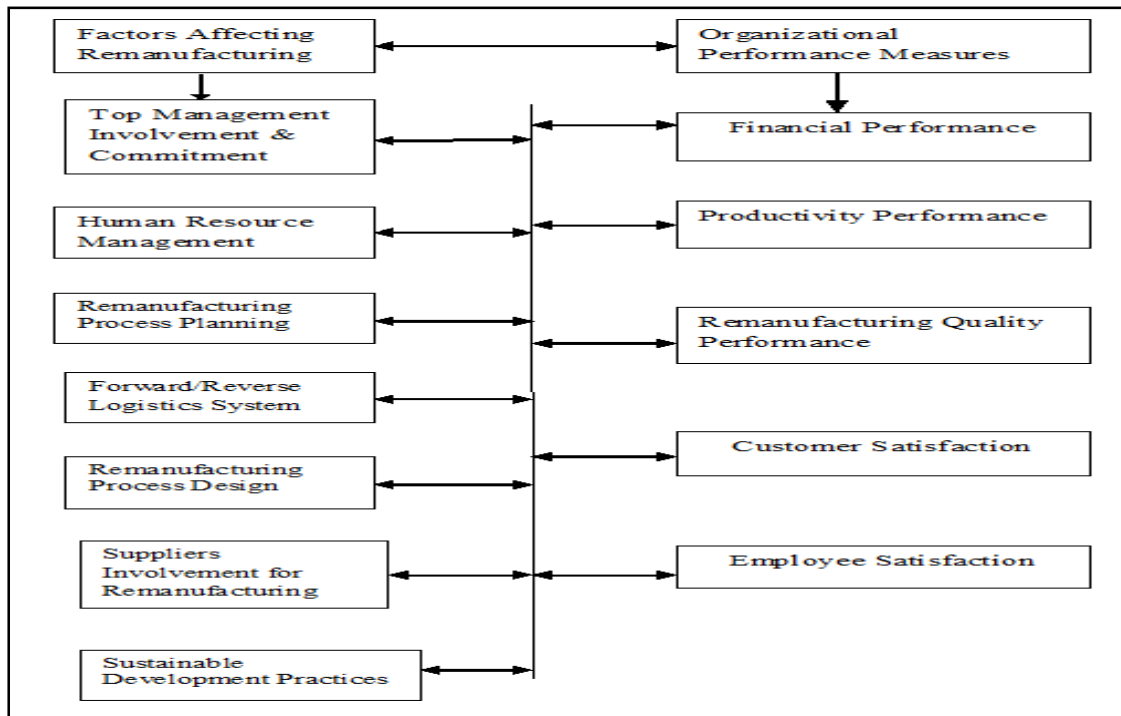


Fig. 1. The test research model

4. ANALYSIS AND RESULTS

Nunnally (1978) stated that an alpha value of 0.70 indicates a strong alpha value with consistent inter-item correlations. Since the alpha value for all the factors is found to be equal to or greater than 0.70, the scales developed here are judged to be reliable. Cronbach's alpha (Cronbach 1951) factor was calculated and is presented in table I. The coefficient was found to be 0.732, indicating that measures have a high degree of criterion-related validity when taken together.

TABLE 1: Reliability statistics of critical success factors

Cronbach's alpha	Cronbach's alpha based on standardized items	N of Items
0.730	0.732	56

4.1 Interpretation of factors affecting remanufacturing industry

This paper proposes described some of the problems facing for establishing remanufacturing industry. Critical Success Factors are described as an industrial point of view in India. Factor 1 accounting for 52.32% of the common variance is named as Top management involvement & commitment. Factor 2, accounting for 50.31% of the common variance is human resource management. The third factor accounts for 45.33% of common variance named as remanufacturing support system. The fourth factor accounts for 30.67% of common variance named as "remanufacturing process". The fifth factor accounts for 22.02% of common variance named as "forward/reverse logistics". The sixth factor accounts for 56.88% of common variance named as "suppliers involvement for remanufacturing" This factor involves suppliers' ISO series certification must for remanufacturing. Environmental partnership with suppliers and OEM's for remanufacturing. Suppliers training and involvement are required for remanufacturing. The seventh factor accounts for 55.97% of common variance named as "sustainable development practices".

4.2 Interpretation of factors affecting organizational performance

In the case of organizations performance measures, a five-factor models are considered. Factor1 accounts for 38.27% of common variance named as "financial performance".

Factor 2, accounts for 41.66% of common variance named as "productivity performance". Factor 3, accounts for 40.44% of common variance named as "remanufacturing quality performance". Factor 4, accounts for 32.08% of common variance named as "customers satisfaction". This is a very important factor which covers customer's complaints or claims about the remanufactured product. Factor 5, accounts for 48.77% of common variance named as "employees satisfaction". The factor involves employment generation through remanufacturing.

4.3. Remanufacturing performance model

Multiple regressions extend the concept of simple linear regression to cases where a researcher wishes to apply several explanatory variables in predicting the value of dependent variable. This analysis is adopted when the researcher has one dependent variable which is presumed to be a function of two or more independent variables the analysis concerning relationship is known as multiple correlations and the equation describing such relationship as the multiple regression equations. Table II shows the multiple regression analysis results remanufacturing factors and organizational performance measures. The remanufacturing performance model of the significant relationship between improvement approaches and performance indicators was developed. The proposed work involves exploratory research on remanufacturing industry. The factors are described some of the problems facing the remanufacturing industry.

4.3.1 Financial Performance model: In this model five input factors are incorporated out of seven input factors, however, the effect of each factor was assessed separately on the output of the model. The model is a financial performance model.

Financial Performance = $3.043 + 0.347 \times \text{Top Management Involvement and Commitment} + 0.279 \times \text{Remanufacturing Support System} + 0.260 \times \text{Suppliers Involvement for Remanufacturing} + 0.134 \times \text{Remanufacturing process} + 0.129 \times \text{Forward / Reverse Logistics} + 0.100 \times \text{Human Resource Management} + 0.117 \times \text{Sustainable development practices}$.

5. ARTIFICIAL NEURAL NETWORK

The following parameters are used for artificial neural network model formulation shown in table III. Figure 2 describes the process in artificial neural network.

TABLE 2: Multiple regression analysis results remanufacturing factors and organizational performance measures.

OPM IF ↓ →	Financial Performance	Productivity Performance	Remanufacturing Quality Performance	Employee Satisfaction	Customer Satisfaction
IF1	0.347	0.202	0.095	0.107	0.135
IF2	0.100	0.381	0.162	0.236	0.128

OPM IF ↓ →	Financial Performance	Productivity Performance	Remanufacturing Quality Performance	Employee Satisfaction	Customer Satisfaction
IF3	0.279	0.377	0.559	0.221	0.232
IF4	0.134	0.131	0.128	0.107	0.120
IF5	0.260	0.125	0.135	0.189	0.096
IF6	0.129	0.086	0.048	0.144	0.141
IF7	0.117	0.049	0.188	0.584	0.522
Intercept	3.043	1.109	1.007	1.006	1.178
Multiple R ²	0.750	0.868	0.778	0.823	0.776
F-value	4.947	10.881	5.125	9.360	11.776

TABLE 3: Details of ANN model formulation parameters.

Method	Multilayer perception
Minimum units in hidden layer	49 (Three times the total No. of factors)
Maximum units in hidden layer	56
Initial Lambda	0.0000005
Initial Sigma	0.00005
Interval offset	± 0.5
Minimum relative change in training error	0.0001
Minimum relative change in training error ratio	0.001
Software used	SPSS V 20

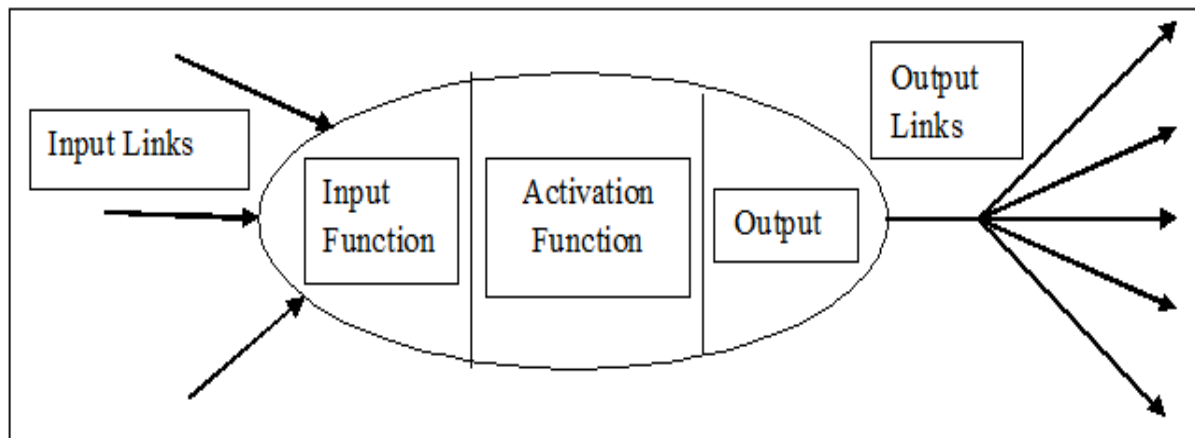


Fig. 2. Artificial neural network

ANN is a non-linear data-driven self-adaptive approach has shown that all the models have correctness of at least 90.4 % and above. The overall percent correctness of 91.9% is also very high. Table IV shows the percent correct prediction for performance measures. ANN is a tool for validation of structured model/ framework.

6. DISCUSSION AND CONCLUSION

In general, theory and models are needed to be developed and consolidated to establish the relationship between

critical success factors and performance factors. The paper is designed to address this gap in particular for the remanufacturing industry. The purpose of this paper is to understand the concept of remanufacturing in industrial sectors and to identify the critical factors and performance measures factors for manufacturing industries in India. The data was tested for normality test, reliability test, validity, adequacy test and internal consistency. The data cleared all these tests and was ready for analysis. Each CSF's of the model was examined and suitable measures were identified

to measure them. The explorative method was used for finalization the priority of CSFs. The various input and output parameters were grouped into seven and five factors respectively. The constitutions of these factors were confirmed by using an item to scale loading. The correlations between seven input factors and five output factors were obtained. The relations were obtained using multiple regression analysis. The relations were optimized using linear programming techniques. These optimized performance measure factors were integrated to form the model for remanufacturing industry. ANN is a non-linear data-driven self-adaptive approach which shows all the models have correctness. ANN is a tool for validation of structured model/ framework.

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Ranking the Barriers of Food Supply Chain for Better Control over Food Safety

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Abstract: In present era, a significant number of people are getting affected because of consuming low-grade food. As a result, consumers are becoming more concerned about the food safety and quality of food products. This perception of consumers forces organization to work not only on quality but also on the food safety issues. This study is focused over identifying and prioritizing the barriers of food supply chain for food safety practices in food organization. Fuzzy DEMATEL approach is adopted in this study to distinguish cause and effect barriers of food supply chain for food safety practices. This study utilizes the fuzzy DEMATEL method which can recommend the most vital barriers having effect on other barriers. Fuzzy set theory deals with sources of indecision or vagueness that is ambiguous and non-statistical in nature.

Keyword: Fuzzy DEMATEL, Food Safety, Food Supply Chain, Food Supply Chain Barriers

1. INTRODUCTION

Food might be characterized as "safe" if it affirms perceived national/worldwide principles as far as its substance, showcase introduction and kind of distribution channel. Food safety covers precautions against all types of health threats directly or indirectly caused by foods (Giray and Özkan, 2012). A dangerous food item can occur at any link of food supply chain from beginning through planting, treating, gathering, preparing, transportation, retail, dissemination, stockpiling, dealing with, arrangement, and disposition. An effective sustenance items safety management can state food product situations, incidents, and outbreaks by nations (Boddie et. al. 2014). In food supply chain, producer has to face issues like seasonality in creation, weather factor, adulteration and use of chemical hazards, pressure of good quality raw materials and worth decay between various stations of supply chain. Because of these particular attributes of nourishment items, it is indispensable for industrial producers to contract providers to ensure the supply of crude materials as far as the correct volume, quality, place and time with keeping product safe to consume (Bloemhof et al., 2015). Consumers are more concerned about quality and safety of food. Food processing industries are at high pressure to follow environment policies and provide good as well as safe food to customer, at the same time keeping the profit maximized. Small and medium type organization generally ignores or show reluctance towards adapting food safety measures. Food safety implementation is affected by three factors production characteristics, organizational characteristics and employee characteristics (Ball et al. 2009). Adequate training and education with full management commitment will motivate workers to apply food safety implementation in organization. Due to globalization things consumer used

to eat decades ago have been replaced or modified, e-commencing has been entered in this field. These modifications also increase the risk of food safety. A large amount of harvested food gets wasted because of not having proper understanding and collaboration for food safety. The goal of this study is to identify the food supply chain barriers which loath the food safety practices in food supply chain and prioritization will be assigned to the barriers with application of fuzzy DEMETAL.

2. LITERATURE REVIEW

The extensive literature reviews were carried out related to Food Safety in food supply chain. The several papers were selected related to food safety and food supply chain related subjects. There are various concepts, conflicting definitions and overlapping views among the researchers and practitioners, but central theme is still the same for all of them. This study tried to find out different FSCBs, these authors dealt with while doing their research.

Due to emerging trends of globalization of food production a worldwide integrated system has been introduced for food production and distribution (Trienekens and Zuurbier, 2007). It is necessary to improve food safety practices, social standards, management behavior and involvement of government & public bodies etc. (Taylor Joanne, 2011). The role of government plays a vital role to achieve food safety at all level for that it is recommended that government should provide economic support to establish food safety mechanism in these firms and should support them to sustain such systems (Karaman et al., 2011). Lack of practical skill and knowledge, resistance to change, lack of funding and lack of understanding about issues influence food safety implementation in organization (Mensah and

Julien, 2011). Collaboration with suppliers and logistics service providers with them can significantly diminish risks and subsequently improve profits and lead to revenue growth (Chaudhuri A. et al., 2016). The food warning system is required to help managers of food manufacturing firms to identify food safety risk in advance (Wang and Yue, 2017). Arendt et al. (2015) find that there are eight motivators and ix barriers which affect food safety practices by employee. Different organizations suffer different problems regarding food safety implementation and it depends upon there the size of the organization. Poor food processing firm design is the result of lack of food safety practices and lack of justifiable practices (Hasnan et al., 2014).

Griffith et al. (2010) assess the food safety culture in food supply chain. A total of six possible groupings including: food safety management systems and style; food safety leadership; food safety communication; food safety commitment; food safety environment and risk perception were acknowledged as “culture” factors that could contribute to food safety performance. These can form the basis for evaluating food safety culture and how this may be done practically along with the creation of a positive food safety culture is discussed. Management is traditionally talked about in food safety but a distinction is drawn between this and food safety leadership.

TABLE 1: FSCB and References

Barrier code	Barriers Name	Description	Reference paper
FSCMB1	Lack of Top Management Commitment	Top management is not focusing on food safety and their commitment towards food safety is poor.	Ball et. al. (2008), Arpanutud et. al. (2009), Griffith et al. (2010), Mensah and Julien (2011) Taylor Joanne (2011),
FSCMB2	Lack of Clear Understanding of Food Safety Requirements	Not having proper understanding about the necessity of food safety practice for business.	Yepp and Fairman (2004), Arpanutud et. al. (2009), Taylor Joanne (2011),
FSCMB3	Lack of Motivation & Reward	Rewards are considered as one of the influencing factor for employee’s performance. Workers need to be appreciated and motivated to implement food safety as they are sole responsible for food safety implementation at ground-level.	Arpanutud et. al. (2009), Taylor Joanne (2011), Yepp and Fairman (2004), Griffith et al. (2010), Mensah and Julien (2011), Narayanamurthy and Gurumurthy (2015)
FSCMB4	Lack of Fund for Food Safety Implementation	Proper funding for food safety practices is necessary as food safety implementation requires a complete planning and infrastructure.	Arpanutud et. al. (2009), Yepp and Fairman (2004), Karaman et al. (2011), Miewald et. al. (2013), Hasnan et al. (2014)
FSCMB5	Lack of Food Safety Policy & Strategies Planning	Management need to strategically develop and plan various policies in such a way that it can be implemented at ground-level with ease.	AruomaOkezie I. (2006), Trienekens and Zuurbeir (2007), Miewald et. al. (2013), Arendt et al. (2015)
FSCMB6	Lack of Facilities & Equipment	Not having proper facilities and equipment will affect food safety practices.	Ball et. al. (2008), Mensah and Julien (2011), Arendt et al. (2015)
FSCMB7	Lack of strict Law Enforcement by the Government	It is necessary that apart from forming the rules, government need to make sure about their enforcement.	Yepp and Fairman (2004), Trienekens and Zuurbeir (2007), Arpanutud et. al. (2009), Mensah and Julien (2011), Taylor Joanne (2011)
FSCMB8	lack of Organizational Structure to Support Food Safety	Not having basic requirement for implementing food safety in organization.	Mensah and Julien (2011), Miewald et. al. (2013)

Barrier code	Barriers Name	Description	Reference paper
FSCMB9	Lack of Organizational Food Safety Methodologies	Organization need to adopt different methods for food safety which requires commitment towards food safety.	AruomaOkezie I. (2006), Griffith et al. (2010), Pedersen et al.(2016)
FSCMB10	Lack of Food Safety Practices	Employees are not willing to adopt predefine standard process of food safety in business processes.	Ahmed et al. (2005), Ball et. al. (2008), Arpanutud et. al. (2009), Griffith et al. (2010), Taylor Joanne (2011), Fahrion et al. (2013), Karaman et al. (2011)
FSCMB11	Lack of Training and Education	The action of teaching a person about importance of food safety and its necessity.	Ball et. al. (2008), York et al. (2009), Taylor Joanne (2011), Fahrion et al. (2013), Vieira Luciana Marques et al. (2013), Arendt et al. (2015)
FSCMB12	Poor Packing and Handling of Food Product	Packaging and handling are the technology of enclosing or protecting products for distribution, storage, sale, and also refers to the process of designing, evaluating, and producing packages.	Ahmed et al. (2005), Ball et. al. (2008), Arendt et al. (2015), Narayanamurthy and Gurumurthy (2015)
FSCMB13	Lack of Standard Format for Food Inspection	Step by step guidelines for the inspection.	Griffith et al. (2010), Shukla et al. (2014), Wang and Yue (2017)
FSCMB14	Lack of Benchmarking Practices	Benchmarking is comparing one's business processes and performance metrics to industry bests and best practices from other companies	Griffith et al. (2010), Mensah and Julien (2011), Moazzam et al. (2012)
FSCMB15	Lack of Performance Measures	The process of collecting, analysing and reporting information regarding the performance of an individual, group, organization, system or component.	Aramyan et al. (2007), Mensah and Julien (2011), Griffith et al. (2010),

Methodology:-This paper integrates the fuzzy sets and DEMATEL method to evaluate food supply chain barriers f. The next section discusses both methodologies.

Fuzzy Set:-A definite amount of fuzziness exists in terms of people's opinions, interpretation and perception. The theory intends to describe uncertain or fuzzy data in the environment. Instead of merging various skills, motivations, ideas and opinions of a specific or group decision maker, it is advisable to transform the linguistic terms into fuzzy numbers (Zadeh, 1965).. Human opinion generally described by equivocal language, like 'very low',

'low', 'medium', 'high' and 'very high'. The fuzzy set is express by the membership function. In this context, a triangular fuzzy number can be defined as a triplet $\tilde{A} = (l, m, r)$ where l, m and r denote lower, medium and upper numbers of the fuzzy sets and $l < m < r$. The membership function of a triangular fuzzy number can be expressed given below. It represents the grade of any element x of X that have the partial membership to A. The fuzzy set theory enables the membership functions to work over the range of real numbers [0, 1]. A fuzzy set comprises elements which have different degrees of membership in it.

TABLE 2: Definition and Membership Function Of Fuzzy

Fuzzy Number	Definition	Membership function (l, m, r)
0	Very low influence	(0, 0, 0.25)
1	Low influence	(0, 0.25, 0.5)
2	Medium influence	(0.25, 0.5, 0.75)
3	High influence	(0.5, 0.75, 1)
4	Very high influence	(0.75, 1, 1)

$$\tilde{A} = \{(x, \hat{u}(x))\} \quad X \in x$$

Where $\hat{u}$ is the membership function and $X = \{x\}$ represents a collection of elements x .

$$\hat{u} = \begin{cases} 0 & x < l \\ \frac{x-l}{m-l}, & l < x < m \\ \frac{r-x}{r-m}, & m < x < r \\ 0 & x > r \end{cases}$$

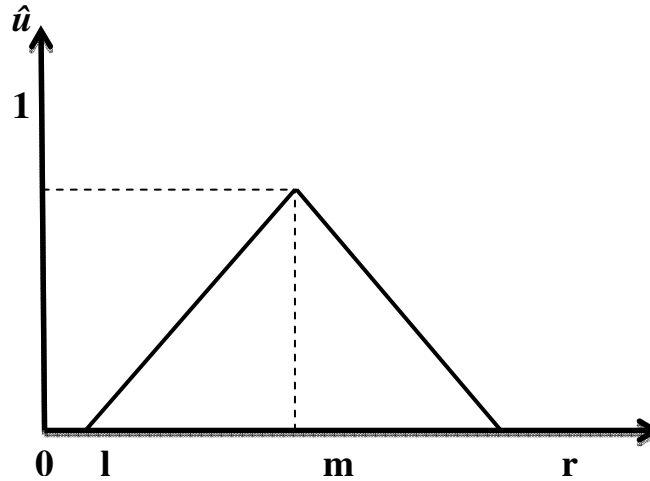


Fig. 4.1. Triangular Fuzzy Number

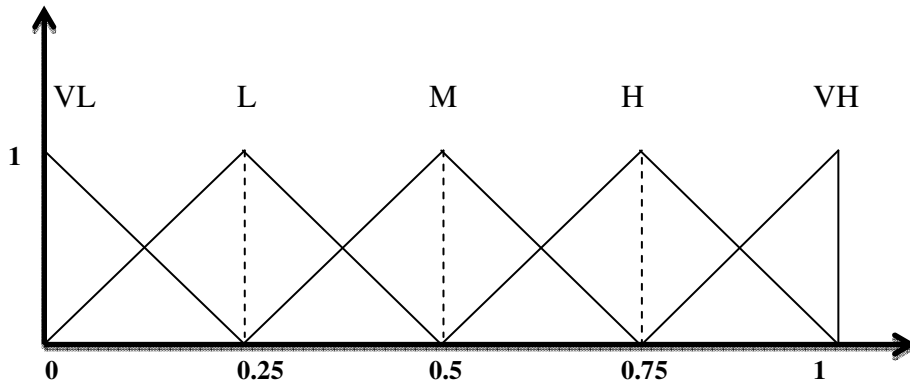


Fig. 4.2. Fuzzy Rating and Their Membership Function

Figure 4.1 shows a triangular fuzzy numbers. The equivalent relationship between the linguistic terms and triangular fuzzy numbers can be found out in accordance with Table 4.1. Consequently, fuzzy rating and their membership function are illustrated in Figure 4.2

This study utilizes the triangular fuzzy number for getting the ideal clarification from group decision making. Fuzzy linguistic variables deal with human response as a part of their language. Fuzzy aggregation processes must comprise a defuzzification step. The most commonly used method is Centroid method (Center-of-gravity method) (Yager and Filev, 1994). But this method is not able to distinguish two

different- shaped fuzzy numbers which can be converted into the same crisp number using Centroid method (Wu and Lee, 2007). Therefore, this paper employs CFCS (Converting Fuzzy data into Crisp Scores) proposed by Opricovic and Tzeng (2003) for de-fuzzification procedure.

According to the process of CFCS method (Opricovic and Tzeng, 2003), the left and right scores are first determined by fuzzy min and fuzzy max based on the fuzzy numbers obtained in the group evaluation phase. And then the final crisp score is calculated as a weighted average based on the membership function. The CFCS (Converting Fuzzy data into Crisp Scores) defuzzification method is appropriate for

the fuzzy aggregation process. The CFCS method gets a better crisp value (Chang et. al. 2011). According to membership functions, the total score can be found out as a weighted average mean the degree of criterion i that affects criterion j and fuzzy questionnaires n ($n = 1, 2, 3, \dots, h$). The CFCS method involves a five-step algorithm as follows.

Step 1. Normalization

$$xr_{ij}^n = (r_{ij}^n - \min l_{ij}^n) / \Delta_{min}^{max} \quad (1)$$

$$xm_{ij}^n = (m_{ij}^n - \min l_{ij}^n) / \Delta_{min}^{max} \quad (2)$$

$$xl_{ij}^n = (l_{ij}^n - \min l_{ij}^n) / \Delta_{min}^{max} \quad (3)$$

Where $\Delta_{min}^{max} = \max r_{ij}^n - \min l_{ij}^n$

Step 2. Evaluate the normalized value from right and left:

$$xrs_{ij}^n = xr_{ij}^n / (1 + xr_{ij}^n - xm_{ij}^n) \quad (4)$$

$$xls_{ij}^n = xm_{ij}^n / (1 + xm_{ij}^n - xl_{ij}^n) \quad (5)$$

Step 3. Evaluate total normalized crisp values:

$$x_{ij}^n = [xls_{ij}^n (1 - xls_{ij}^n) + xrs_{ij}^n \times xrs_{ij}^n] / [1 - xls_{ij}^n + xrs_{ij}^n] \quad (6)$$

Step 4. Evaluate crisp values:

$$Z_{ij}^n = \min l_{ij}^n + x_{ij}^n \times \Delta_{min}^{max} \quad (7)$$

Step 5. Integrate crisp value

$$Z_{ij} = \frac{1}{n} \sum_{n=1}^n Z_{ij}^n \quad (8)$$

4.2 DEMATEL Method

Decision-making trial and evaluation laboratory (DEMATEL) method was developed in Battelle memorial institute of Geneva by science and human affair program in between 1972 and 1976. The DEMATEL method is based on graph theory. It is a comprehensive method for building and analyzing a structural model involving causal relationship between complex barriers (Wu and Lee, 2007). The DEMATEL method differentiates barriers into cause and effect groups. Prioritization of barriers can be achieved by this method. The digraph portrays a basic concept of contextual relation among the elements of the system, in which the numeral represents the strength of influence. Hence, the DEMATEL method can convert the relationship between the causes and effects of factors into a comprehensible structural model of the system.

The steps of DEMATEL process summarized below:

Step 1. Construct the initial direct-relation matrix by the help expert's panel, and obtain the assessments about direct

impact between each pair of elements. Converting the linguistic assessments into crisp values, we obtain the direct-relation matrix $A = [a_{ij}]$

Where A is a $n \times n$ non-negative matrix, a_{ij} indicates the direct impact of factor i on factor j ; and when $i = j$, the diagonal elements $a_{ij} = 0$.

Step 2. Normalize the initial direct-relation matrix. The normalized direct-relation matrix $T = [t_{ij}]$ can be obtained through Eq. (4.9). All elements in matrix T are complying with $0 \leq t_{ij} \leq 1$, and all principal diagonal elements are equal to 0.

$$T = \frac{1}{\max(\max_{1 \leq j \leq n} \sum_{j=1}^n a_{ij})} A \quad (9)$$

All elements in matrix T are complying with $0 \leq t_{ij} \leq 1$, and all principal diagonal are equal to 0.

Step 3. Acquire the total-relation matrix S using the Eq. (4.10) in which I is an $n \times n$ identity matrix. The element s_{ij} indicates the indirect effects that factor i have on factor j , so the matrix S can reflect the total relationship between each pair of system factors.

$$S = T(1 - T)^{-1} \quad (10)$$

Where S is total- relation matrix

Step 4. Calculate the sum of rows and columns of matrix S . To make the conclusion more noticeable, we compute D_i and R_i through Eqs. (4.11) and (4.12) respectively. The sum of row i , which is denoted as D_i , represents all direct and indirect influence given by barrier i to all other barriers, and so D_i can be called the degree of influential impact. Similarly, the sum of column j , which is denoted as R_i can be called as the degree of influenced impact, since R_i summarizes both direct and indirect impact received by barrier j from all other barriers.

$$D_i = \sum_{1 \leq j \leq n} S_{ij} \quad j = (1, 2, 3, 4 \dots n) \quad (11)$$

$$R_i = \sum_{1 \leq i \leq n} S_{ij} \quad i = (1, 2, 3, 4 \dots n) \quad (12)$$

The D_i shows the total effects by the i^{th} barrier on the other barriers directly and indirectly. The R_i shows the total effects on the j^{th} barrier by other barriers directly and indirectly. The $D_i + R_i$ shows the cumulative of the effects on and by the i^{th} barrier on the whole system. The $D_i - R_i$ shows the net effect of i^{th} barrier on the system. If $D_i - R_i$ is positive then the i^{th} barrier will be the cause of the system and negative value will denote the net receiver.

Step 5. The priority weight can be given to the FSCBs by below:

$$W = \frac{\sum_{j=1}^n D_i + R_i}{\sum_{i=1}^n \sum_{j=1}^n D_i + R_i} \quad (13)$$

Case Study:-The organization A is public sector organization. It was established in 1965 and currently it has more than 26000 employees working allover India. The organization A consists of major department Procurement, Movement, Storage, Quality Control, Engineering, HR Activities Handle by Top Management. It is a government funded organization and not a profit making organisation. Subsidy is given by Govt. of India. The organization has ISO 9001:2000 certification. The organization A is engaged in procurement, storage and distribution of harvested food commodities.

Application of Fuzzy DEMATEL:- For this study, eight experts have been taken who has experience as well as knowledge in concern field

Step 1:- Identification of most vital barriers of food supply chain for food safety (FSCB) by literature review and by expert opinion.

Step 2:- Construct the initial direct-relation matrix by the help expert's panel, and obtain the assessments about direct impact between each pair of elements.

TABLE 3:Sample Assessment Data of Expert 1 Opinion

FSCB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FSCB1	0	M	H	VH	VL	VL	H	VH	H	L	M	M	M	H	H
FSCB2	VH	0	L	H	M	H	L	H	VH	M	H	VL	VH	M	M
FSCB3	M	H	0	M	M	H	L	VL	L	VL	M	M	M	L	H
FSCB4	H	M	M	0	H	M	M	M	VL	H	H	M	L	M	M
FSCB5	L	VL	H	VH	0	VL	L	H	VH	L	L	H	L	H	H
FSCB6	VL	H	VH	H	H	0	L	VL	H	L	M	M	L	VH	M
FSCB7	H	L	H	M	VH	H	0	H	L	L	H	H	L	M	H
FSCB8	M	M	VL	VL	M	L	VL	0	M	VL	L	M	M	VH	M
FSCB9	VL	VL	VH	VH	VH	M	L	M	0	VH	M	VH	H	VH	M
FSCB10	VH	M	L	VH	VL	L	VL	H	VH	0	M	M	H	H	H
FSCB11	H	M	L	VL	H	VL	H	L	VL	VL	0	L	VH	M	M
FSCB12	M	H	VL	M	VH	H	M	H	VL	H	H	0	L	M	H
FSCB13	H	L	L	H	L	H	VH	H	L	M	VL	L	0	M	M
FSCB14	M	L	M	VL	M	H	H	L	M	VL	VH	VH	H	0	L
FSCB15	VL	H	H	VH	H	VL	M	VL	H	H	H	L	M	H	0

TABLE 4: De-fuzzification of Initial Direct- Relation Matrix using CFCS Method

FSCB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FSCB1	0	0.5	0.033	0.967	0.5	0.73	0.5	0.23	0.73	0.033	0.967	0.73	0.5	0.967	0.967
FSCB2	0.967	0	0.73	0.967	0.73	0.73	0.967	0.967	0.967	0.23	0.967	0.73	0.73	0.967	0.967
FSCB3	0.967	0.5	0	0.5	0.033	0.033	0.73	0.5	0.033	0.73	0.73	0.5	0.5	0.23	0.73
FSCB4	0.033	0.73	0.967	0	0.73	0.73	0.23	0.033	0.73	0.967	0.23	0.73	0.033	0.73	0.5
FSCB5	0.73	0.23	0.23	0.23	0	0.5	0.967	0.73	0.033	0.5	0.73	0.23	0.73	0.5	0.73
FSCB6	0.5	0.5	0.73	0.5	0.73	0	0.967	0.967	0.033	0.033	0.5	0.5	0.73	0.73	0.5
FSCB7	0.033	0.73	0.23	0.033	0.73	0.5	0	0.73	0.73	0.73	0.033	0.73	0.23	0.23	0.73
FSCB8	0.73	0.23	0.73	0.5	0.033	0.73	0.5	0	0.5	0.5	0.033	0.5	0.967	0.5	0.5
FSCB9	0.033	0.73	0.033	0.73	0.967	0.23	0.033	0.967	0	0.73	0.73	0.5	0.5	0.967	0.5
FSCB10	0.033	0.73	0.033	0.033	0.73	0.967	0.033	0.73	0.5	0	0.5	0.033	0.967	0.5	0.033
FSCB11	0.5	0.5	0.73	0.73	0.23	0.033	0.23	0.033	0.73	0.033	0	0.73	0.23	0.5	0.5
FSCB12	0.73	0.967	0.23	0.033	0.033	0.23	0.033	0.5	0.73	0.5	0.23	0	0.73	0.967	0.967
FSCB13	0.033	0.73	0.5	0.73	0.5	0.5	0.73	0.23	0.73	0.033	0.967	0.967	0	0.5	0.23
FSCB14	0.73	0.23	0.73	0.5	0.73	0.033	0.23	0.73	0.23	0.73	0.73	0.5	0.5	0	0.5
FSCB15	0.967	0.5	0.5	0.967	0.033	0.967	0.73	0.5	0.5	0.967	0.5	0.73	0.73	0.73	0

TABLE 5: Average Initial Direct Relation Matrix

FSCB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FSCB1	0.00	0.70	0.59	0.85	0.59	0.50	0.44	0.79	0.73	0.44	0.68	0.62	0.56	0.91	0.85
FSCB2	0.70	0.00	0.37	0.70	0.73	0.64	0.64	0.70	0.73	0.46	0.73	0.41	0.76	0.79	0.82
FSCB3	0.82	0.62	0.00	0.53	0.18	0.24	0.53	0.41	0.12	0.53	0.64	0.53	0.53	0.28	0.76
FSCB4	0.24	0.59	0.73	0.00	0.64	0.62	0.34	0.21	0.47	0.76	0.37	0.67	0.18	0.67	0.47
FSCB5	0.50	0.14	0.40	0.57	0.00	0.35	0.70	0.64	0.29	0.50	0.44	0.46	0.47	0.53	0.70
FSCB6	0.41	0.62	0.70	0.59	0.64	0.00	0.76	0.70	0.24	0.12	0.56	0.47	0.55	0.67	0.50
FSCB7	0.24	0.61	0.40	0.15	0.70	0.56	0.00	0.70	0.58	0.53	0.29	0.76	0.28	0.34	0.76
FSCB8	0.67	0.34	0.56	0.44	0.27	0.53	0.44	0.00	0.47	0.44	0.12	0.50	0.85	0.50	0.44
FSCB9	0.06	0.47	0.29	0.79	0.94	0.37	0.09	0.82	0.00	0.79	0.61	0.65	0.53	0.91	0.47
FSCB10	0.29	0.67	0.18	0.29	0.56	0.76	0.06	0.64	0.65	0.00	0.50	0.24	0.79	0.53	0.15
FSCB11	0.50	0.50	0.58	0.53	0.37	0.09	0.43	0.12	0.47	0.12	0.00	0.58	0.40	0.53	0.53
FSCB12	0.67	0.79	0.22	0.24	0.29	0.40	0.21	0.50	0.56	0.59	0.34	0.00	0.61	0.79	0.82
FSCB13	0.24	0.53	0.44	0.73	0.50	0.53	0.79	0.37	0.53	0.18	0.65	0.79	0.00	0.50	0.34
FSCB14	0.64	0.22	0.70	0.32	0.67	0.29	0.40	0.58	0.28	0.56	0.79	0.59	0.59	0.00	0.47
FSCB15	0.70	0.62	0.53	0.94	0.24	0.65	0.59	0.41	0.62	0.82	0.56	0.53	0.61	0.73	0.00

Step 3:- Normalize the generalized Initial direct-relation matrix (T) by using equation 3. Normalized matrix is shown in Table 6.

TABLE 6: Normalized Matrix (T)

FSCB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FSCB1	0.000	0.076	0.063	0.092	0.064	0.054	0.048	0.085	0.079	0.048	0.073	0.067	0.061	0.098	0.092
FSCB2	0.076	0.000	0.040	0.076	0.079	0.070	0.070	0.076	0.080	0.050	0.079	0.045	0.082	0.086	0.089
FSCB3	0.089	0.067	0.000	0.057	0.019	0.026	0.057	0.045	0.013	0.057	0.070	0.057	0.057	0.030	0.082
FSCB4	0.026	0.063	0.079	0.000	0.070	0.067	0.037	0.023	0.051	0.083	0.040	0.073	0.019	0.073	0.051
FSCB5	0.054	0.015	0.043	0.062	0.000	0.038	0.076	0.070	0.032	0.054	0.048	0.049	0.051	0.057	0.076
FSCB6	0.045	0.067	0.076	0.064	0.070	0.000	0.082	0.076	0.026	0.013	0.061	0.051	0.060	0.073	0.054
FSCB7	0.026	0.066	0.043	0.016	0.076	0.060	0.000	0.076	0.063	0.057	0.032	0.082	0.030	0.037	0.082
FSCB8	0.073	0.037	0.060	0.048	0.029	0.057	0.048	0.000	0.051	0.048	0.013	0.054	0.092	0.054	0.048
FSCB9	0.007	0.051	0.032	0.086	0.102	0.040	0.010	0.089	0.000	0.086	0.067	0.070	0.057	0.098	0.051
FSCB10	0.032	0.073	0.019	0.032	0.060	0.082	0.007	0.070	0.070	0.000	0.054	0.026	0.086	0.057	0.016
FSCB11	0.054	0.054	0.063	0.057	0.040	0.010	0.046	0.013	0.051	0.013	0.000	0.063	0.043	0.057	0.057
FSCB12	0.073	0.086	0.024	0.026	0.032	0.043	0.023	0.054	0.060	0.064	0.037	0.000	0.066	0.086	0.089
FSCB13	0.026	0.057	0.048	0.079	0.054	0.057	0.086	0.040	0.057	0.019	0.070	0.086	0.000	0.054	0.037
FSCB14	0.070	0.024	0.076	0.035	0.073	0.032	0.043	0.063	0.030	0.060	0.086	0.064	0.064	0.000	0.051
FSCB15	0.076	0.067	0.057	0.102	0.026	0.070	0.063	0.045	0.067	0.089	0.060	0.057	0.067	0.079	0.000

Step 4:- After getting normalized fuzzy direct-relation matrix, the fuzzy total relation matrix can be achieved by equation 9. The fuzzy total relation matrix is shown in Table 7

Step 5. The sum of rows and the sum of columns are separately denoted as D and R within the total-relation matrix S through the formulas given in equation 11 and equation 12. Sum of D+R will denote the cumulative impact on the system by the barrier whereas D-R will show the net impact of barrier on or by the system. By evaluating D+R and D-R cause and effect barriers can be identified.

Step 6. For prioritizing the barriers the summation of D+R will be divided to each barrier. Hence the weight of the barrier will be achieved. This weight will signify the importance of the barrier on food safety in food supply chain. To calculate weight, equation 13 will be referred.

TABLE 7: Total Relation matrix (S)

FSCB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FSCB1	0.168	0.218	0.201	0.168	0.167	0.180	0.150	0.180	0.154	0.164	0.163	0.185	0.160	0.183	0.195
FSCB2	0.202	0.165	0.180	0.180	0.180	0.183	0.165	0.153	0.168	0.134	0.155	0.183	0.168	0.149	0.183
FSCB3	0.203	0.198	0.147	0.195	0.159	0.196	0.159	0.173	0.166	0.157	0.167	0.155	0.171	0.184	0.183
FSCB4	0.214	0.213	0.176	0.143	0.161	0.182	0.138	0.160	0.191	0.162	0.158	0.153	0.182	0.157	0.204
FSCB5	0.185	0.192	0.171	0.188	0.137	0.149	0.160	0.156	0.187	0.158	0.131	0.169	0.146	0.166	0.193
FSCB6	0.191	0.207	0.157	0.183	0.189	0.144	0.165	0.165	0.164	0.149	0.131	0.161	0.170	0.152	0.185
FSCB7	0.184	0.204	0.172	0.162	0.145	0.191	0.127	0.157	0.145	0.167	0.149	0.146	0.184	0.157	0.178
FSCB8	0.215	0.218	0.173	0.164	0.187	0.195	0.178	0.138	0.197	0.171	0.138	0.173	0.166	0.178	0.177
FSCB9	0.198	0.205	0.145	0.166	0.175	0.154	0.160	0.156	0.134	0.140	0.149	0.164	0.163	0.147	0.176
FSCB10	0.207	0.225	0.163	0.194	0.183	0.196	0.181	0.159	0.209	0.135	0.157	0.163	0.178	0.186	0.170
FSCB11	0.204	0.215	0.184	0.169	0.175	0.182	0.148	0.141	0.182	0.154	0.126	0.159	0.178	0.185	0.181
FSCB12	0.210	0.205	0.183	0.195	0.166	0.185	0.184	0.173	0.191	0.163	0.170	0.145	0.196	0.181	0.189
FSCB13	0.202	0.220	0.181	0.161	0.197	0.185	0.152	0.189	0.181	0.160	0.154	0.180	0.141	0.178	0.189
FSCB14	0.234	0.235	0.175	0.202	0.190	0.203	0.165	0.178	0.214	0.173	0.171	0.201	0.183	0.150	0.206
FSCB15	0.230	0.236	0.204	0.189	0.165	0.193	0.190	0.174	0.184	0.183	0.172	0.200	0.174	0.180	0.160

TABLE 8: The Score of Importance Weight and Priority of Each FSCBs

Codes	Barriers Name	D	R	D+R	Weight	Rank
FSCB1	Lack of Top Management Commitment	3.0456	2.636	5.6816	0.0721578	2
FSCB2	Lack of Clear Understanding of Food Safety Requirements	3.1536	2.548	5.7014	0.0724101	1
FSCB3	Lack of Motivation & Reward	2.6124	2.614	5.2259	0.0663709	9
FSCB4	Lack of Fund for Food Safety Implementation	2.6585	2.595	5.2530	0.066715	6
FSCB5	Lack of Food Safety Policy & Strategies Planning	2.5769	2.488	5.0653	0.064331	13
FSCB6	Lack of Facilities & Equipment	2.7177	2.513	5.2307	0.066432	8
FSCB7	Lack of strict Law Enforcement by the Government	2.4225	2.468	4.8902	0.0621069	14
FSCB8	lack of Organizational Structure to Support Food Safety	2.4526	2.666	5.1182	0.0650027	10
FSCB9	Lack of Organizational Food Safety Methodologies	2.6666	2.433	5.0995	0.064765	11
FSCB10	Lack of Food Safety Practices	2.3716	2.706	5.0771	0.0644806	12
FSCB11	Lack of Training and Education	2.2911	2.584	4.8750	0.0619135	15
FSCB12	Poor Packing and Handling of Food Product	2.5370	2.737	5.2742	0.0669842	5
FSCB13	Lack of Standard Format for Food Inspection	2.5610	2.670	5.2314	0.0664408	7
FSCB14	Lack of Benchmarking Practices	2.5330	2.880	5.4129	0.0687453	4
FSCB15	Lack of Performance Measures	2.7692	2.833	5.6018	0.0711441	3

3. FINDINGS AND DISCUSSION

By extensive literature review and expert discussion, Fifteen FSCBs have been identified. The inter-relations amid different barriers have been found out from academicians and a panel of industry experts. Food safety implementation is a duty for each and every food industry. To be competitive in market, organization should focus quality as well as safety of food product. Food safety implementation in organization restores the trust of customer about the safety of product which going to be consumed and hence ultimately increases the productivity. By applying fuzzy DEMATEL method weight priority is given to the FSCBs according to their impact on the system is evaluated. Fuzzy DEMATEL method is generally used to find inter-relationships among framework barriers, and visualizes this structure by cause-effect relationship diagram. D_i value of each barrier finds out by adding row value of the barrier which shows i^{th} barrier's impact on other barriers to achieve them and R_i signify the impact of other barriers over the i^{th} barrier. Prioritization is carried out by $D+R$ which signifies the cumulative influence of barrier on system.

Lack of clear understanding of food safety requirements and lack of top management commitment has given highest priority as their weights are 0.0724 and 0.0721 respectively. Lack of performance measure and lack of benchmarking practices are given third and fourth priorities with weights 0.0711 and 0.0687 respectively. Rest of the priority weights are mentioned in the Table 8.

4. CONCLUSIONS

Food safety in food supply chain refers to the range which covers preparation, handling, transporting, storage and serving of food such that it must be prevented to foodborne illness. This study is focused on evaluating the barriers of food supply chain for food safety implementation. Fuzzy DEMATEL method is implemented on the barriers to prioritize the FSCBs. The priority weight is evaluated in this method by calculating $D+R$ which signifies the cumulative influence of FSCB on the system. Lack of clear understanding of food safety requirements FSCB1 is most significant FSCB as it has weightage maximum with value 0.0724 and given first priority. The result suggested that it is management's responsibility to communicate the necessity of food safety implementation to the all the entities of food supply chain and for implementing the food safety in food supply chain management should be aware of food safety related issues and challenges. The organization should focus more on management commitment towards food safety implementation. Lack of top management commitment FSCB1, Lack performance measures FSCB15 has given top priority after lack Clear understanding of food

safety requirements FSCB2. The priority of other FSCB for food safety has given in Table 8.

The result of the study will help the policy makers and managers to understand the food safety issues in food supply chain and enable them to take better steps for minimizing the food loss either quantity wise or quality wise during the movement of food. Like other studies this research also suffers with limitation. In the prioritization of FSCB, proposed fuzzy DEMATEL rely upon limited number of experts. It is based on expert's knowledge and experience on food safety. Any biased opinion can influence the result. More number of experts can be consulted to get more accurate results.

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Sustainability in Agri-Food Supply Chain

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Abstract : This paper describing the challenges faced by agri-food industry for sustainability and the significant role of agri-food supply chains. Also discuss the practices for sustainable food supply chain likely characteristics of sustainable innovation for agri-food supply chain and in what way industries practicing higher levels of performance related to economic, social, and environmental perspective.

Keywords: Sustainability, agri-food supply chain, agri-food industry

1. INTRODUCTION

Today we have numerous organizations working all day and night to find out better ways of matching their operations and economic logics for the protection of resources which are of utmost importance for survival of human society. The new and better ways that are to be developed will have to be implemented cautiously keeping in mind their sustainability. A great number of studies done recently show that if we progress in same way as of now, considering the rate of depletion of resources and rate of increment of human population, we will run short of resources providing us food even with all industries combined.

The whole agri-food supply chain works through a complex system linked using many acting points known as actors. The major cause which is responsible for unsustainability in system is none other than this current and complex structure with many actors in it with conventional mind-set. Modern day supply chains, specially the food supply chains are the consequences of old system but with modern day organizations which tells us how most of them their design models on economic bases as the primary benchmark of growth and effectiveness. In order to satisfy their conventionally set targets most of them practice unsustainable methods. The history of organization and its management have been well documented (Piore&Sabel, 1984; Stout, 2012; Williamson, 1995). When an industry works with financial point of view as its base, they work with scale and leverage strategy. Scale and leverage are a by-product of the overriding concern for efficiency, productivity and shareholder wealth (Albert, 1993). For solution to current problems, Innovation can prove to be a boon for mankind. Companies will have to develop more sustainable consumption models. But two vital points need to be kept in mind while doing so-First of all, the companies need to shift their focus only from getting more value out of sustainable methods they are going to apply. Most solutions currently adopted are strategic remedies

rather logical solutions. They need to realise the important role they play as an organization in society. Coming to second issue, the innovation should be sustainable by itself and work effectively in long term rather than providing short term solutions. Moreover, the implementation of innovations should be supportive and done after analysing the sustainability problems in current agri-food supply chain.

2. CHALLENGES FACED BY AGRI-FOOD INDUSTRY FOR SUSTAINABILITY

Currently, the food industry has been going through unexperienced changes, thus, making it the most competitive industry thriving for sustainability in current scenario whether it's about share of production, consumption or employment. To give you an idea of this, here are some statistics –In Europe, food industry revenue is constituted by 14.5% of total manufacturing revenues, 15.5% of the employment and 12.5% of the value added in manufacturing. Also, the food industries which deal internationally here are small in number but with a wide range of products for sell. Another interesting fact is that 99% of the companies and 63% of the employment is accounted for by small and medium enterprises (SMEs). (ECSIP Consortium 2016; Fooddrink, Europe, 2015). In case of USA, the agricultural industries account for a total of 4.8% of the total GDP (stats as of 2014).

The mentioned figures show how highly competitive is Agri-Food Industry. The critical point here is that main producers or price takers i.e. farmers have a very little bargaining power and participation. Also not to forget that industry is largely dependent on natural environment. For example – Farming is one of the most primitive technologies which gives us most important products, all of which rely on the natural environment. Although, it largely involves using surface water and deep root in lands, we need to realize now that we have been doing more harm than good to Earth by our cultivation methods which

involve excessive use of fertilizers and chemical products in greed for better yield. (EU Standing Committee on Agriculture Research [SCAR], n.d). Among all the activities contributing in emission of Green House gases, 15-28% comes from Food Systems in developed countries. (Garnett, 2011). This in turn is leading to environmental instability which makes it an important concern to be resolved at the need of the hour.

Another challenge is a social issue. The rate at which human population is increasing, we are expected to cross 8 billion mark by 2030 and make it over 9 billion till it's 2050. (UN, 2013). Calculating our current production capabilities and our development rate, we will need 60% more global food supplies which is a serious matter as this is a tremendous amount. We need to know that around 33% of the food produced globally gets wasted; this number needs to reduce drastically if we need sustainable development and better future not only for Agri-Food Industry but also for whole human society. Social issues also revolve around the health of consumers. As per recent surveys, we have over 600 million obese people and 1.9 billion overweight people, which is a huge disappointment knowing that other than this category we also have people who waste their food when a considerable part of this world does not even have proper access to food resources.

On summing up in brief, we can conclude that Agri-Food Industry faces a total of three major challenges – First, Food production largely depends on environmental, human and physical resources. Second, Consumer awareness for food is a vital matter. The sooner we get aware of negative impacts of unsustainable methods used to grow food we consume; the better conditions will get. Third, Complex network of supply chain with different level actors in it needs to change. Conflicts will arise if only a few or one of the actors sticks to sustainable method when others are not capable of it.

3. SUPPLY CHAIN AND AGRI-FOOD INDUSTRY

Food we consume gets produced using complex processes. Involving industrialized and mass production processes with many diverse actors. We need sustainable development in order to use our resources efficiently. There are three types of sustainability that should be considered for utilising the resources:

Economic Sustainability: While developing sustainable methods in Supply Chain and Agri-Food Industry, we should remember the limitations of capital and invest accordingly. The new methods should not take a heavy toll on capital or take down an industry to loss, making it a non-appreciable idea.

Social Sustainability: Social Sustainability involves providing social equality for workers and not harming their social rights at work place.

Environmental Sustainability: The most important factor for any industry to continue in long term is to keep in mind the idea of environmental sustainability. The process adopted for manufacturing should be environment friendly and not cause a Water Pollution, Land Pollution or Noise Pollution.

The food sector was the first of its kind which required to develop better methods as a result of sustainability issues (Fritz & Schiefer, 2008) and the matter of concern is that we are still looking for innovative solutions for bringing sustainability in supply chain and agri-food industry for public welfare. Siddh, et al., (2015) discussed that sustainable development of perishable food supply chain is related to economic, social and environmental sustainability of supply chain.

4. PRACTICES FOR SUSTAINABLE FOOD SUPPLY CHAIN

The previous works in this section have shown that how sustainable development in food supply chain is possible by adopting the practices which aim at 'harm reduction' and those stuck to 'harm elimination' (Pagell & Shevchenko, 2014). The sustainable supply chains should be economically viable and not harm, or perhaps provide the aid to natural and social environment (Pagell & Wu, 2009). In order to achieve sustainability, we need to improvise on all three sustainability factors and this can be achieved in following manner –

Environmental Sustainability: This part of sustainability can be worked upon by conserving natural resources using practices such as reducing the consumption of natural resources, reducing the emissions into the air, land, and water, and preserve the soil along with biodiversity. We should also practice the three R's which are recycle, reduce and reuse as they can drastically reduce the amount of waste produced. We should also keep in mind the animal welfare which involves proper breeding conditions, thus eliminating the veil acts of cruelty, and promotes handling and housing of animals safely.

Social Sustainability: Social sustainability can be improvised though taking better measures in health and safety practices, securing human rights of every individual and adopting the practices which support welfare and development of community. Social sustainability promotes the idea of living a healthy lifestyle, proper education and realising the responsibility of consumption. Social sustainability at workplace is a vital aspect as well which can be achieved by employing females and giving them equal wages and opportunities as well. Also, the workplace should have a healthy atmosphere and hygienic conditions. Many organisations have already taken a step towards social sustainability with extra activities such as childcare and philanthropy.

Economic Sustainability: The first step in order to gain economic sustainability is by adopting fair trade practices. Root actors in supply chains should keep transparency in system with no abuse of power and use fair methods while keeping limited confidentiality. Ensuring fair trade practices will not only lead to proper distribution of profits but also monitor the working of whole chain in an ideal manner which in turn will lead to an increment in consumer awareness as these processes will result in establishment of fixed premium rates on every article.

5. SUSTAINABLE INNOVATION FOR AGRI-FOOD SUPPLY CHAIN

As we have thoroughly studied how supply chain in agri-food is going through unsustainable methods of production currently, we need to focus on proper utilisation of resources and adopt sustainable methods of production, as current methods are putting future development at risk. The only way to have sustainable methods in this field is through innovation. It is through innovation that we can enhance our sustainable effectiveness (Hansen, Grosse-Dunker, & Reichwald, 2009; Horn & Brem, 2013; Schaltegger & Wagner, 2011; Siddh, et al., 2017). We need innovation right from grass root level to the highest level, thus, revolutionising our whole current structure. Innovations have to range from developing better technologies and processes, crafting out goods and services in better ways and finally making swap in our present business models.

The above mentioned in approaches are important in order to take over the diverse challenges in sustainability dimensions. It can be concluded in this context that the above discussed practices, if applied, will bring up a better system than our traditional supply chain, also making it more transparent and easier to manage.

6. CONCLUSION

After the great inputs from many scholars and suggestions from many researchers, it is safe to conclude that if we do not adopt sustainable methods for supply chain in agri-food industries, we might end up facing the greatest famine of all time as a result of the rate at which our resources are depleting and our population is increasing. In order to avoid this problem, we need to adopt sustainable methods and improvise in Social, Economic and Environmental Sustainability. For sustainable method, s we need Innovation – a sustainability oriented innovation which will change our current supply chain system with a better one right from the lowest to the highest level. These changes are possible only through efforts of industries as well as through awareness in consumers. For this world to last long and have better future, we need to rise and realise the importance of our resources and work for their

conservation while we develop better and sustainable methods for the human life to thrive on this planet.

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Sustainable Supply Chain Management in Thermal Power Sectors of India

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Abstract: Rapid industrialization activities in developing countries like India, to meet the demand of its growing population has increased its energy needs manifold. This in turn has led to installation of huge number of coal-fired thermal power plants in India. More power plants has not only intensified environmental degradation but also increased logistics related emissions, waste production, non-disposability of byproducts. Implementation of Sustainable Supply Chain Management (SSCM) practices in power plants is influenced by a number of interrelated barriers that negatively affects SSCM implementation. This research attempts to explore potential barriers of SSCM. An attempt has been made to prioritize these barriers using Grey Relational Analysis. Lack of Coordination and Internal Population Issues emerge as the most important and least important barriers respectively. Prior knowledge of these barriers and their ranking will help the decision makers to develop suitable strategies that would enable the organizations to reduce their inhibiting impact on SSCM implementation.

1. INTRODUCTION

India depends on hydro-electric, thermal power, nuclear power and wind power industries to meet its energy demands. However, around 70% of total electricity is generated by thermal power sectors in India that use coal as fuel. It has been also estimated that this trend may continue for at least the next 30-40 years. The dependency on thermal power has increased environmental and social hazards significantly in India. Subsequently, thermal power industries (TPIs) are experiencing high pressure from new economic, energy saving and environmental regulations. So, thermal power industries are showing increased interest in adoption of Sustainable Development (SD) practices.

Sustainable development aims in carrying out industrial operations to improve their economic, social and environmental performance (Hussain, 2011). Sustainability concepts in the supply chain has led to the emergence of sustainable supply chain management (SSCM) that emphasizes on management of economic, social and environmental footprints of the organizations as well as encouragement of good governance practices, throughout the lifecycles of goods and services (Grzybowska, 2012). Though, significant growth in SSCM adoption rate has been observed in developed countries, yet Indian industries particularly, TPIs don't share the same enthusiasm. This could be due to their lack of knowledge regarding various influential factors of SSCM, particularly the barriers of SSCM adoption. Hence, attempt has been made in this research to identify various Parameters that hinder SSCM adoption in Indian thermal power industries. Knowledge of these barriers will help the decision makers to formulate proactive strategies to minimize their impact.

2. LITERATURE REVIEW

Growing consciousness regarding environmental and societal issues has triggered one of the greatest revolutions in human thought, uniting the entire world in a fight against the emissions which are produced during industrial activities (Dubey et al., 2015). Particularly the last decade has seen an increased pressure to broaden the accountability of the industries beyond economic performance, for shareholders to sustainability performance, for all stake holders (Labuschagne et al., 2005). Consequently an increased interest was exhibited by organizations in addressing sustainability in their supply chains, which has been described as Sustainable Supply Chain Management (SSCM) that incorporates the triple bottom line of sustainability (Walker and Jones, 2012). Green or environmental aspect of SSCM focuses on minimization of the adverse environmental consequences of various activities of supply chains whereas the second one, social aspect of SSCM ensures ethical as well as decent working conditions of various stakeholders including the suppliers. The third component of the SSCM, the economic aspects ensures local economic generation through purchasing from local suppliers (Walker and Jones, 2012).

3. METHODOLOGY

To determine the most influential barriers causing hindrance in the implementation of SSCM, a standard questionnaire was designed consisting of 28 barriers in the context of Indian thermal power sector. A survey was conducted by sending the questionnaire by mail and personal contacts to different experts, managers, and employees of thermal power industries. The survey was conducted by using likert scale 1 to 5, (i.e, 1= totally

disagree, 2 = partially disagree, 3 = No opinion, 4 = partially agree, 5 = totally agree). The survey responses were analyzed statistically using SPSS to test the reliability and validity. Principal component factor analysis of the survey responses using varimax rotation extracted 10 important barriers. Grey relational analysis (GRA) is implemented to rank these barriers of SSCM in thermal power industries.

4. RESULT AND DISCUSSION

Multi-criteria decision making analysis is used in solving real life decision-making complex problems. Grey Analysis is a fantastic tool for the determination of ranks when the number of criteria and alternatives is countless large. Another important advantage of GRA is its ability to generate satisfactory outcomes using a relatively lesser amount of information (Rajesh and Ravi, 2015) Hence, Grey relational analysis has been employed in this research to rank the identified barriers mentioned below.

1. Resource Limitation
2. Lack of Performance Management Measures
3. Internal Population Issues
4. Operational Issues
5. Lack of Coordination
6. Legislative Issues
7. Lack of Eco-Literacy among Supply Chain Partners
8. Demanding Requirement from NGO's
9. Global Aspects
10. Unacquainted Society

Step-1: Generation of Grey Relations

In a multi attribute decision making (MADM) problem different attributes might require different units for measurement of their performance. Further, certain performance attributes might have a very large range. In addition, existence of attributes having different goals and directions also lead to incorrect results in the analysis (Huang and Liao, 2003). GRA addresses these issues by generating grey relational, where all performance values for each alternative is processed into a comparability sequence, in a process analogous to normalization (Kuo et al., 2008).

For a MADM, if there are m alternatives and n attributes, the ith alternative can be expressed as $Y_i = (y_{i1}, y_{i2}, \dots, y_{ij}, \dots, y_{in})$, where y_{ij} is the performance value of attribute j of alternative i. The term Y_i can be translated into the comparability sequence $X_i = (x_{i1}, x_{i2}, \dots, x_{ij}, \dots, x_{in})$, by use of one of equations 1, 2 or 3.

$$x_{ij} = [y_{ij} - \min \{y_{ij}, i=1, 2, \dots, m\}] / [\max \{y_{ij}, i=1, 2, \dots, m\} - \min \{y_{ij}, i=1, 2, \dots, m\}]$$

$$\text{For } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (1)$$

$$x_{ij} = [\max \{y_{ij}, i=1, 2, \dots, m\} - y_{ij}] / [\max \{y_{ij}, i=1, 2, \dots, m\} - \min \{y_{ij}, i=1, 2, \dots, m\}]$$

$$\text{For } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (2)$$

$$x_{ij} = 1 - \frac{|y_{ij} - y_j^*|}{\max\{y_{ij}, i=1, 2, \dots, m\} - y_{ij}^*, y_{ij}^* - \min\{y_{ij}, i=1, 2, \dots, m\}}}$$

$$\text{For } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (3)$$

The generated grey relation values are shown in Table1

TABLE 1: Grey Relational Analysis

Barrier	Values
1	0.791667
2	0.944444
3	0.736111
4	0.930556
5	1
6	0.791667
7	0.763889
8	0.986111
9	0.805556
10	0.930556

Step-2: Determination of Grey Relational Coefficient:

Scaling of the comparability sequence values into the range [0, 1] is done in this step, shown in table 2. The alternative with larger value of X_i (equal to unity) is assumed to have highest strength. However, chances of existence of such kind of performance attributes are nil. Hence a reference sequence X_0 whose values are equal to 1, is defined and compared with the generated sequence (Tiwari et al., 2014). The reference sequence is expressed as follows.

$$X_0 = (x_{01}, x_{02}, x_{03}, \dots, x_{0j}, \dots, x_{0n}) = (1, 1, \dots, 1, \dots, 1)$$

$$(X_{oj}, X_{ij}) = [\Delta_{\min} + \xi \Delta_{\max}] / [\Delta_{ij} + \xi \Delta_{\max}]$$

$$\text{For } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (4)$$

$$\Delta_{ij} = |X_{oj} - X_{ij}|; X_{oj} = 1$$

$$\Delta_{\min} = \min \{\Delta_{ij}, i=1, 2, \dots, m; j=1, 2, \dots, n\}$$

$$\Delta_{\max} = \max \{\Delta_{ij}, i=1, 2, \dots, m; j=1, 2, \dots, n\}$$

$$\xi = \text{distinguishing coefficient} \in [0, 1]$$

In our case $\xi = 0.5$

TABLE 2: Grey Relational Coefficient

Barrier	Values
1	0.395834
2	0.472222
3	0.368056
4	0.465278
5	0.5
6	0.395834
7	0.381945
8	0.493056
9	0.402778
10	0.465278

Step-3: Finding Grey Relational Grade:

In order to find grey relational Grade, the equation is given as

$$\Gamma(X_0, X_i) = \sum_{j=1}^m W_j \times (X_{0j}, X_{ij}) \text{ For } i=1, 2, \dots, m \quad (5)$$

Step-4: Ranking of Barriers

The ranks of all the Barriers were found out and grey relational grades & their ranks are shown in Table 3.

TABLE 3: Grey relational grades and corresponding ranks (Assuming, 'W' as unity)

Barrier	Values	Rank
1	0.395834	6
2	0.472222	3
3	0.368056	8
4	0.465278	4
5	0.5	1
6	0.395834	6
7	0.381945	7
8	0.493056	2
9	0.402778	5
10	0.465278	4

5. CONCLUSION

The implementation of SSCM is a complex and difficult phenomena, owing to its dependency on several factors. Hence, an attempt has been made in this paper to identify

potential factors those influence SSCM implementation in thermal power plants negatively. Through review of literature and questionnaire based survey 10 such factors were identified which were termed as barriers. Further, Grey relational analysis was used to analyze the inhibiting impact of these barriers and rank them according to their degree of negative impact on SSCM implementation. Lack of Coordination has been identified as the most significant barrier whereas Internal Population Issues as the least significant barrier. Prioritization of the barriers will give an insight to the decision makers to solve SSCM implementation problem in thermal power sectors.

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A Review of End-of-Life Vehicle (ELV) Recycling in India with SWOT Analysis

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Abstract: India is witnessing the exponential growth in vehicle population due to growth in economy, higher incomes, changing lifestyles and easy finance schemes. With increasing population of vehicles the number of End-of-Life Vehicles (ELVs) is also growing. ELVs are mainly recycled by semiformal sector in country. This sector uses primitive methods to recycle ELVs that result in low product recovery, environmental pollution and poses serious threats to human health. This sector has its own strengths and weaknesses. Promoting strengths and working against weaknesses can contribute in the development of sustainable end of life vehicle recycling industry. This paper identifies the problems being faced by the end of life vehicle recycling sector in India and the potentials through SWOT (strengths, weaknesses, opportunities and threats) analysis.

Keywords: ELV recycling, SWOT, India

1. INTRODUCTION

Automobile industry is one of the biggest industries in India and currently witnessing exponential growth in vehicle manufacturing. The factors behind this growth are improved economy, higher incomes, easily available finance and changing lifestyles (Chaturvedi, Chaturvedi and Short, 2012). India is emerging as a fastest growing passenger car market and second largest two wheeler manufacturers in the world. The country produces 13 lakhs passenger vehicles, 4 lakhs commercial vehicles, 76 lakhs two wheelers and around 3 lakhs tractors annually (Automotive Mission plan 2006-16). With the increase in number of new vehicles, the population of End-of-Life Vehicles (ELVs) is also increasing.

An end of life vehicle (ELV) is a specified vehicle which is discarded or is to be discarded by its registered owner as a waste (Go et al, 2011). ELVs are mainly classified as natural ELVs and premature ELVs. Natural ELVs means those vehicles whose life is over due to age and premature ELVs are those whose life have come to end due to unnatural reasons such as an accident, fire, and flood or vandalism damage. As per report of Ministry of Environment, Forest and Climate change (2016) around 9 million vehicles retired in 2015 and more than 20 million will retired by 2025. Figure 1 (a) and (b) Shows the different types of vehicle which will complete their useful life by 2015 and 2025 respectively.

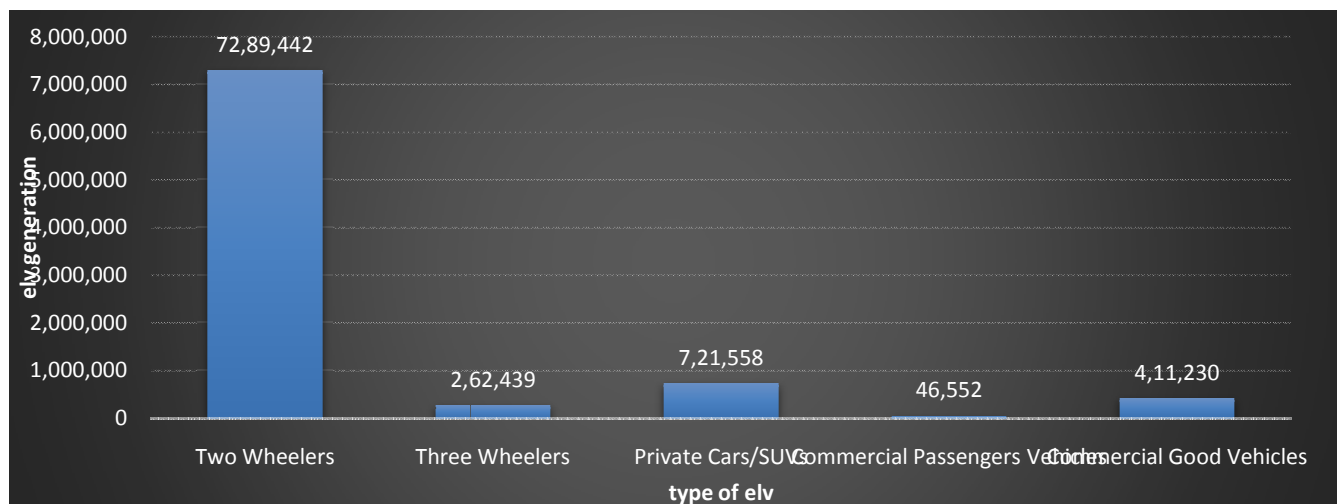


Fig. 1. (a). ELV generation in India by 2015

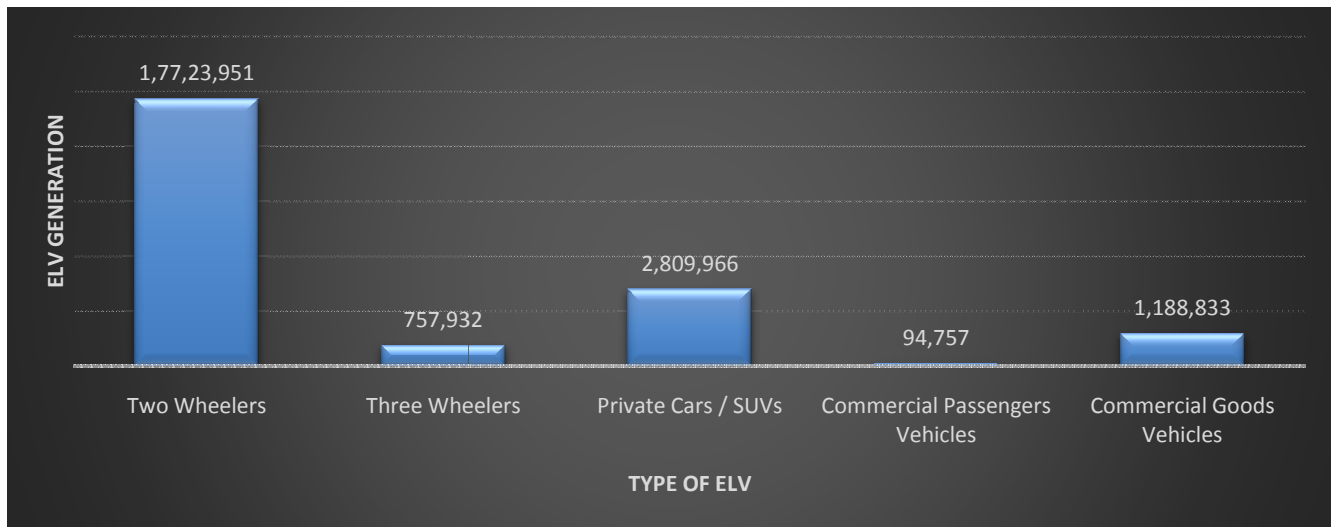


Fig. 1 (b). ELV generation in India by 2025

End-of-Life Vehicle recycling has become a global issue due to economic and environmental reasons. Dismantler/recycler can earn profit by reuse/recycling the valuable parts present in ELVs. ELVs also contain hazardous substances such as waste oil, lubricants, lead acid batteries, air bags and coolants (Chen, Huang and Lian, 2010). If not properly recycled or disposed, these substances may have negative impact on human health and environment.

2. ELV RECYCLING PRACTICES IN INDIA

In India, ELV recycling is carried out by small units in semiformal sector. These units dismantle/recycle the ELV in a haphazard and unscientific manner. This results in low product recovery, environmental pollution and poses serious threats to the health of the employees. Dismantlers/recyclers are interested only in economic gains and do not follow any environmental laws. The ELVs are de-polluted at dismantling units. De-pollution involves removal of engine oils, coolants and lubricants. The drained engine oils are sold to small informal refineries. After de-pollution, the parts/components are removed from ELVs (refer fig 2).



Fig 2. End of life vehicle dismantling

The reusable parts/components are sold to scrap dealer. The non-reusable parts are sent for material recycling. The non-reusable and non-recyclable parts are dumped in an uncontrolled and unregulated fashion (Chaturvedi, Chaturvedi and Short, 2012).

3. SWOT ANALYSIS

SWOT analysis is one of the most straightforward methods used in the analysis of company or industry. The SWOT analysis identifies the strengths, weaknesses, opportunities and threats (Zhang and Chen, 2013). The SWOT analysis on the ELV recycling industry in India will be presented in the following section.

3.1 Strengths

3.1.1 Large number of ELVs

ELV population in India is continuously growing. It is estimated that total ELV generation in country will touch to 20 million by 2025 (Ministry of Environment, Forest and Climate change, 2016). The large number of ELVs indicates sufficient raw material for the recycling industry which is a positive factor.

3.1.2. Employment

ELV recycling business provides job to lakhs of people. It is estimated that more than one lakh families are employed in dismantling and recycling business directly (Mohan Ram, 2012).

3.1.3. Low labor cost

ELV dismantling requires extensive labor. In India, ELVs are manually dismantled in dismantling units. Low labor cost is the main advantage for the development of ELV recycling industry.

3.2 Weaknesses

3.2.1 Lack of ELV legislations/policies

In developed countries like Europe and Japan, ELV legislations play very important role in the development of ELV recycling industry. These legislations commonly set the target of 95% (in terms of weight) recovery of ELVs (Sakai, 2014). At present, India does not have ELV specific legislations/policies to regulate the haphazard and unhygienic recycling practices and to motivate manufacturers to design environmentally friendly vehicles. There is an urgent need to have legislations/policies to reduce environmental pollution and improve the vehicle recovery rate (Mohan Ram, 2012).

3.2.2 Lack of adequate infrastructure and technology

Country does not have bigger storage, dismantling and shredding facilities. The vehicle recycling units are small and they do not have capability and capacity to deal with bigger number of vehicles. ELV recycling businesses lack technologies to identify, separate and recover quality materials (Sivakumar, Barnabas and Anatharam, 2014). These units are not equipped to handle systems like airbags and seat restraints. Country needs to upgrade the infrastructure and develop technologies to deal with more number of ELVs in future.

3.2.3. Absence of manufacturer in ELV recycling

In India, manufacturers do not participate in ELV recycling. There is no co-operation between manufacturers and dismantlers. They do not provide dismantling information or training to the employees of dismantling units. Lack of dismantling information causes difficulty in ELV dismantling, low recovery and increase labor cost. To increase the dismantling efficiency and improve the recovery rate, manufacturers should design the vehicles for recycling and share the vehicle related information with the dismantlers and recyclers.

3.2.4. Low environmental awareness

Environmental awareness of India people is relatively poor. Knowingly or unknowingly everyone is polluting the environment. They are not aware of benefits of ELV recycling. There is a need to enhance environmental awareness through school education, newspaper and seminars and conferences. (Mohan Ram, 2012).

3.3 Opportunities

3.3.1. Efficient and viable ELV recycling industry

Current ELV recycling practices in India causes serious environmental pollution and loss of natural resources. With proper planning, co-operation among the government, manufacturers, recyclers, dismantlers and consumers,

country has a good opportunity to establish modern, efficient and viable ELV recycling industry.

3.3.2. Conserve natural resources

Environmentally friendly recycling and disposal of ELVs not only avoid the negative impact on the environment but also reduce the consumption of natural resources (Chen, Huang and Lian, 2010). It has been estimated that India can recover 2 million tons of steel, 1, 80, 000 tons of aluminum, 75, 000 tons each of rubber and plastic and some other material by 2020 (Mohan Ram, 2012). This will definitely reduce the consumption rate of primary materials and save the energy.

3.3.3 Preserve foreign exchange

Automobile recycling preserves foreign exchange (Mohan Ram, 2012). Due to economic development, the demand for raw material is consistently growing. Every year steel makers in India imports more than 5 million tons of scrap for recycling into finished steel. The scrap recovered from the ELV recycling will help to reduce the import of scrap and save foreign exchange.

3.4 Threats

3.4.1. Haphazard and unhygienic recycling process:

The dismantling/recycling unit uses primitive methods which are very unhygienic and poses serious threats to environment and human health (Garg, Sharma and Gangacharyula, 2014). Precious materials are not recovered in an environmentally friendly way and non-usable and non-recyclable parts are dumped in uncontrolled and unregulated fashion (Sharma et al, 2016). For example, Copper is recovered by burning of insulation which results in release of dioxins into the atmosphere.

3.4.2 Recycling units in residential areas

Most of the recycling units are located in the residential areas like Mayapuri in Delhi, Puda Pet in Chennai, Shivaji market in Bangalore and Loharchawl and Chor bazaar in Mumbai (Report on End-of-Life Vehicles Worldwide, 2012). Most of these units do not follow decontamination procedure. The hazardous fluids are spilled and disposed on the ground. The working area in unit is contaminated with oil, coolants and other fluids. This affects the health of employees as well as nearby residents. To avoid this, it is necessary to relocate these recycling units away from the residential areas.

3.4.3. Uncertainty about policy implementation

The implementation of policies influences the development of industry. Existing environmental laws and regulations have not been performed effectively. The implementation

of proposed policies is an important challenge for the development of ELV recycling industry.

3.4.4 Lack of efforts in designing green vehicles

ELV recycling rate and level of difficulties in dismantling are directly related to design of vehicles. These factors should be considered while designing the vehicles. Unfortunately, manufacturers in India have shown very little interest in designing the vehicles for recycling (DFR) and design for assembly (DFA).

4. CONCLUSION

Mature ELV recycling industry has not yet established in India. ELV recycling is presently carried out by semiformal sector. Haphazard and unhygienic recycling practices lead to environmental pollution and low recovery. Country does not have ELV legislation to regulate the recycling practices. Manufacturers neither participate in ELV recycling nor do they co-operate with recycling operators. The ELV recycling industry in India lacks adequate infrastructure and advance technologies.

The ELV legislations/policies in developed countries like Europe, Japan and South Korea have a significant impact on the world. India needs to learn from the experiences of these countries in the establishment of sustainable ELV recycling industry. Country need to develop strategies to encourage environmentally friendly ELV recycling practices, upgrade infrastructure and develop technologies. An efforts are needed to improve the consumer awareness through school education, print and electronic media and by conducting seminars and training programs.

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Examining Penetration of Knowledge Flow in SC for Indian Manufacturing Organizations

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Abstract: A long and discontinuous Supply Chain (SC), inadequate policy support, inefficient information and Knowledge Flows have constrained manufacturing development in the past in India. Now a day, a very crucial objective for any organization is to keep uninterrupted supply of required products, at right time and place. Manufacturing companies achieve global operations through various strategic business alliances including joint ventures and outsourcing, etc. SC has assumed a leading operations strategy position in manufacturing over the past 10 years. While dealing with the global competition, organisations realize efficient knowledge management has been identified as one of the key requirements for effective SC. Therefore, primary objective of this study is to determine penetration of knowledge flow in the Indian manufacturing organisations using survey method.

Keyword: Supply Chain, Knowledge Flow, Survey Method

1. INTRODUCTION

The slow pace of growth in the manufacturing sector at this stage of India's development is not an acceptable outcome. Therefore, to increase exports as well as provide its internal market with domestically produced manufactured goods that compete with imports, India must manufacture a much larger volume of products at competitive costs and quality. While dealing with the global competition, organisations realize efficient knowledge management has been identified as one of the key requirements for effective SC (Liu et al., 2013). The shape of global manufacturing SCs has changed dramatically with the application of computers and telecommunications (Planning Commission, Government of India).

The success of knowledge flow implementation is totally depend upon the successful implementation of SCKFEs and this research is focused on Indian manufacturing organizations. It is necessary to identify the level of penetration of implementation of SCKFEs in Indian manufacturing organizations. So an attempt is made through this study to assess the level of penetration using a survey of Indian manufacturing organizations.

The survey is executed through a well-designed and validated instrument in conformance with the objectives. Through a well-developed and validated Instrument/Questionnaire, in total 269 responses were collected from industries. The level of penetration of SCKFEs is determined by using descriptive statistics through analysis of collected responses. For each item the mean and standard deviation is calculated.

2. LITERATURE REVIEW

Gathering of knowledge from different sources is not easy and its spread among individuals, organizations and SC members is even more complex. Knowledge flow enablers can help to reduce the problems associated with the knowledge flow adoption in SC (Kurtz et al., 2012). Knowledge is recognized as an important source of competitive advantage and hence there has been increasing academic and practitioner interest in understanding and identifying the enablers that contribute to effective knowledge flow between SC actors. These factors are called as SCKFEs (He et al., 2013). This study identified 21 (see Table 1) SCKFEs through literature review, and in consultation with experts it has been categorised into four different categories namely "characteristics of knowledge flow", "strategic", "knowledge flow mechanism" and "organisational".

TABLE 1: List of SCKFEs

Enablers	References
Characteristics of the knowledge flow	
Transferability of knowledge	Lawson and Potter (2012)
Updated knowledge	Lawson and Potter (2012)
Validated Knowledge	Jokinen (1997)
Strategic	
Top management support	Huang et al. (2010)
Strategic planning	Wu (2008)
Integration of knowledge	Chen et al. (2013)

Knowledge flow methodology	van Hoof (2014)
Relative power	Cai et al. (2013)
The motivation of source and recipient firms	McLaughlin (2010)
<i>Knowledge flow mechanism</i>	
Strategic relationship	He et al. (2013)
Employee training and site observation	van Hoof (2014)
Continuous communication	Al-Karaghoul et al. (2013)
Personalization	Yang (2012)
IT infrastructure	Myers and Cheung (2008)
Codification	Cai et al. (2013)
<i>Organizational</i>	
Collaborative alliance	Chong and Bai (2014)
Organizational culture	Yang et al. (2013)
Common language and terminology	Alguezaui and Filieri (2010)
Organization's reputation	Christopher and Gaudenzi (2009)
SC partners goals	Myers and Cheung (2008)
SC structure	Pan et al. (2013)

3. INSTRUMENT/QUESTIONNAIRE DEVELOPMENT

A well designed and validated instrument/questionnaire is required to determine the level of penetration of knowledge flow in SC for Indian manufacturing organizations. This section elaborates that how to develop an instrument/questionnaire for the above stated objective. This instrument/questionnaire has two sections and was designed to collect detailed information about, the profile of respondents and organizations (14 Questions), Penetration of SCKFEs (21). Five point Likert scale is selected for scaling responses, as it is a psychometric scale which is generally involved in research that uses instrument/questionnaires.

A survey instrument/questionnaire was developed in order to test the research model. After framing the instrument/questionnaire it was pretested from the same industry experts and academia. A pilot study was conducted with 34 manufacturing organizations. Data collected from 34 organizations were tested for mean, standard deviation, missing data, kurtosis and skewness and found within the range. Hence all the measurement items were kept as it is for large scale data collection.

4. LARGE SCALE DATA COLLECTION METHODOLOGY

The survey was confined to India only and the data collection took six months. The survey was conducted in two modes. The offline mode preferred for the industries which are within the reach. The 350 printed questionnaires were distributed to industries with cover letter indicating the purpose and significance of the study. Out of 350 questionnaires the 62 respondents are completed the questionnaire and return back. This represents a response rate of 17.71% (calculated as 62/350). The survey was also conducted by the web-based method. The web base questionnaire with the cover letter indicating the purpose and significance of the study was emailed to 700 target respondents along with web-link (<http://goo.gl/forms/xmL6nECPkO>). To encourage response, follow-up emails and telephone calls were made to non-respondents after we sent out the questionnaires. Finally, we received 219 returned questionnaires, twelve of which were incomplete and thus discarded. A total of 207 completed questionnaires provided the study with a response rate of approximately 29.57%. The total 269 are responses collected by offline survey and web based survey. One of the concerns of the survey research is that the information collected from respondents might have a non-response bias. The test for non-response bias was executed to check for any significant difference between the early and late respondent (the difference between early and late is three months) considering the late respondent as non-respondents. The results of the independent sample t test showed no significant difference between two response waves ($p > 0.05$). Thus, it can be summarized that the non-response bias is not a cause for concern. The one way ANOVA test was carried out to check for any significant difference for type of organization (automobile, machine tools/equipments, electrical/electronics, process and FMCG), job position of respondents (senior management level, middle management level and lower management level) and found no significant difference at $p > 0.05$. In addition, a Harman's one-factor test was conducted because the data were collected from a single type of respondent at a single point in time.

5. DATA ANALYSIS

The collected data through developed instrument/questionnaire was analysed by using statistical package for the social science (SPSS) software. The descriptive statistics analysis has been done to analyse this data. The descriptive analysis displays univariate summary statistics for several variables in a single table and calculates standardized values and can be ordered by the size of their means (in ascending or descending order). By sorting the means in ascending order, the level of SCKFEs and vital enablers implemented in organizations were identified. The

implementation status of each enabler base on mean score is again validated from the panel of industry experts.

5.1 Characteristics of Knowledge Flow

The penetration of 'characteristics of knowledge flow' is moderately implemented in Indian manufacturing organization. The mean for this practice is 4.01 and very low standard deviation of 0.82. Now a day in implementation of knowledge flow in SC characteristics of knowledge flow play an important role. The characteristic of knowledge flow improves the quality and understandability of knowledge. The mean and standard deviation values of each SDA are given as follows (see Table 6.1).

TABLE 2: Descriptive statistics for characteristics of knowledge flow

Sr. No.	Item Description	Mean	Std. Deviation
1	Transferability of knowledge	3.94	0.81
2	Updated knowledge	4.07	0.75
3	Validated knowledge	4.04	0.92
		4.01	0.82

5.2 Strategic Enabler

The penetration of 'strategic enabler' is high in implementation of knowledge flow in SC for Indian manufacturing organization. The mean for this category is 3.95 and standard deviation of 0.74. The strategic enabler presents number of knowledge flow plans which positively influencing SC performance and competitiveness. Every manufacturing organization should work for the sharing of knowledge and improve SC performance. The mean and standard deviation values are shown as follows (see Table 2.4).

TABLE 3: Descriptive statistics for strategic enabler

Sr. No.	Enabler	Mean	Std. Deviation
1	Top management support	4.10	0.74
2	Strategic planning	4.04	0.77
3	Integration of knowledge	4.16	0.75
4	KF methodology	3.71	0.78
5	Relative power	3.84	0.65
6	The motivation of source and recipient firms	3.87	0.76
		3.95	0.74

5.3 Knowledge Flow Mechanism

The penetration of 'knowledge flow mechanism' is reasonable in implementation of knowledge flow in SC in Indian manufacturing organization. The mean for this category of knowledge flow mechanism is 3.98 and standard deviation of 0.82 (see Table 6.3). Every organisation should have some kind of mechanism (e.g. information technology infrastructure or regular meetings to support the storing, sharing and utilization of knowledge among employees), facilities (e.g. conference rooms or open access areas for informal gathering or dialogues).

TABLE 4: Descriptive statistics for knowledge flow mechanism

Sr. No.	Enabler	Mean	Std. Deviation
1	Strategic relationship	3.84	0.83
2	Employee training and site observation	4.05	0.75
3	Continuous communication	4.22	0.73
4	Personalization	3.90	0.77
5	IT infrastructure	3.91	0.96
6	Codification	3.94	0.86
		3.98	0.82

5.4 Organizational Enabler

The penetration of 'organizational enabler' is also moderately penetrated in implementation of knowledge flow in SC for Indian manufacturing organization. The mean for this practice is 3.97 and standard deviation of 0.81 (see Table 6.5). Organizational enablers are the vision and knowledge, the relationship and resources, and the culture of the organization that will need to do to develop and implement its strategy. Organisational knowledge reflects the view of how resources should be used in order for the firm to benefit.

TABLE 5: Descriptive statistics for organizational enabler

Sr. No.	Enabler	Mean	Std. Deviation
1	Collaborative alliance	3.81	0.79
2	Organizational culture	3.96	0.77
3	Common language and terminology	3.94	0.85
4	Organization's reputation	3.97	0.85
5	SC partners goals	3.86	0.73
6	Supply chain structure	4.26	0.84
		3.97	0.81

6. CONCLUSION

This study also checked the status of level of penetration of SCKFEs in Indian manufacturing organizations. The data of 269 respondents were collected through an instrument/questionnaire and it is analyzed by using statistical package for social science (SPSS). The descriptive statistics is used to represent the level of penetration of SDAs in Indian Manufacturing Organizations. The current study could provide an insightful understanding of the penetration of SCKFEs in the Indian manufacturing organisations. This is considered as a vital contribution since after all, the ultimate aim of management is to improve firm performance. The identified SCKFEs in different set will be useful to the SC managers and knowledge management executives for implementing knowledge flow in SC. These sets of SCKFEs will definitely assist them in understanding the SCKFEs and their effect.

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Understanding the Benefits of Green Supply Chain Management and the Framework for a Generic Approach in Measuring the Organizational Performance

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Abstract: In today's competitive environment, industries are experiencing an increased pressure to reduce cost, improve quality and reduced delivery time to sustain in the market place. Hence, they have narrowed down focusing on the factors of their sustainability and other influencing factors, in such a way that the environmental concerns are ignored. Many actions of this underlying issue in the industries is restrained due to economic reasons, and hence there is a need to show necessary guidance and proof of economic benefits that would help in the broader application of the concept, such as Green Supply Chain Management (GSCM). In this context, there is a need to also spread awareness of GSM Practices. This study has been an attempt to review the extant literature to understand the benefits of GSCM and also to provide for a generic framework to measure the organizational performance. In this context, few hypotheses are conceptualized and proposed, which could be tested in the future.

Keywords: GSCM, Qualitative benefits, Quantitative benefits, Motivations, Economic performance, Environmental Performance, Operational Performance

1. INTRODUCTION

Environmental concerns nowadays are leading to new customer requirements, beyond conventional functionalities such as, quality and cost, while relating to how products are made, how long they last, and how they can be disposed of (Peattie, 1999). Environmental pollution has been a serious problem, and one of the major sources of emission is toxic gases from the manufacturing industries. To overcome this problem and to reduce the environmental pollution, manufacturing industries are required to incorporate the concept of "Green" in their supply chain". Srivastva (2007) defined: Green Supply Chain Management (GSCM) as integrating environmental thinking into supply-chain management, including product design, material sourcing & selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life. Winroth (2009) stated that Green Supply Chain aims at continuous improvement of industrial processes and products to reduce or prevent pollution to air, water and land. Richards (1994) identified Green manufacturing as one that meets the customer demands for environmentally sound products, development of recycling schemes, minimizing the materials use and selecting the materials causing low environmental impact. Environmental concerns may also emerge due to their suppliers and in turn trouble the company's environmental performance and thus greening of the supply chain will help companies avoiding and controlling the potential challenge.

The reason for commitment to the greening of SCM was due to the environmental impacts of production. Hence the perspective changed from greening as a burden to greening as a potential source of competitive advantage in business (V. D. R. Guide Jr., L. N., 2002). The aim of this study has been to explore the benefits of green practices and to identify the organizational performance parameters.

2. LITERATURE REVIEW

There are different practices of GSCM involved internally as well as externally by organizations to add into account for the development of the country's economy, especially in countries like India. Karthik Kudroli (2014) has concluded three major types in this connection.

1. Less power and paper consumption termed as internal environment management practice.
2. Developing suppliers to practice green purchasing termed as external GSCM practice.
3. Waste minimization, investment recovery and environmental requirements after cooperating with the customers.

Any energy saving measure can be termed as green measure and such energy saving measure in the supply chain can be defined as GSCM. Manufacturers are responsible for the entire product life cycle right from its

origin to its disposal. According to VinodSambarani (2016), they have an important role to play in enabling green manufacturing by the use of waste free and emission free energy sources through which they can provide products to green consumers, who respond to global warming and climate change.

3. ACTIVITIES IN GSCM

Ninlawan et al. (2010) had done a study on Green Implementation on electronics industries, wherein they proposed activities of GSCM. These activities comprise of all the processes in GSC, starting from green procurement to green manufacturing to green distribution, till the recycle and waste management of the product.

3.1 Green Design of Product and Processes

Green Design deals with design for waste minimization (Srivatava 2007). The main social objective of Green Design is to ensure the sustainable society in regard with the available resources and ecological health. Hendrickson et al. (2001) suggested that the concept of green design mainly focusses on three goals for sustainable future: 1) Reduce or minimize the use of non-renewable resources 2) Manage renewable resources to ensure sustainability and 3) Reducing or eliminating the toxic and other harmful emissions to the environment, including emissions contributing to the environment.

3.2 Life Cycle Assessment (LCA)

In this technique the environmental effects and resources needed for development of new product or process are clearly traced out from the raw material supplier to the manufacturer and further to its disposal. LCA draws a boundary for eliminating or stopping the growth of inventory emissions and resources (Hendrickson et al. 2001). Gungor & Gupta (1999) described the LCA as a process of evaluating the environmental, occupational health and the resource related with the consequences of a product through all phases of its life.

3.3 Green Procurement

Green procurement is defined as eco-friendly purchasing, which involves activities like reduction, reuse and recycling of materials in the process of purchasing. It involves integration of environmental issues into purchasing decisions based on price, performance and quality. Elements of Green procurement programs are:

1. Recycled content products
2. Energy efficient products and energy efficient standby power devices
3. Alternative fuel vehicles, alternative fuels and fuel efficient vehicles
4. Bio based products And

5. Environmental protection priority chemicals

These elements help in selecting the product for the manufacturing process.

3.4 Supplier Selection

For effective GSCM, it is important that the materials and parts are purchased only from Green partners. The supplier who controls hazardous substances in the industries and has obtained green certificate can be considered as an efficient supplier (Ninlawan et al. 2010).

3.5 Green manufacturing

It is defined as the production processes, which use inputs with relatively low environmental impacts and they are highly efficient and generate little or no waste or pollution. Winroth (2009) stated that green manufacturing aims at continuous improvements of industrial processes and products to reduce or prevent pollution to air, water and land. The challenges associated with green manufacturing are meeting the customer demand for environmentally sound products, development of recycling schemes, minimizing the material use and selecting the materials that have low environmental impact (Richards 1994). Green manufacturing can lead to lower the raw material cost, increase the production efficiency and reduce the environmental and occupational safety expenses. The power consumption can also be reduced to a greater extent by implementing green manufacturing processes. It enhances environmental consciousness through 3 Rs (reduce, reuse and recycle) activities (Zhu 2007). Green manufacturing relies on a long term thinking, because the environmental impact created by industries has been there for many years and hence a sudden change will cause more investment on their capital, but if a longer time frame is considered, it is accountable. When a proper organizational approach is established the initial step of choosing options for green manufacturing is making an inventory by production operation of inputs used and the waste generated. The inputs used may be energy, raw materials and water. The waste generated includes off-specification products, solid wastes and inputs returned to their suppliers (Atlas & Florida 1998). They also stated that the other non-product outputs are sent to recycling treatment or discharged into the environment. The second step of choosing the option for green manufacturing process is selecting the important non product output and focussing on the waste streams in the product (Florida 1998). The third step proposed by Florida was generating the options to reduce the non-product outputs at their origin. These options are product changes, process change, input change, increased internal reuse of wastes and better housekeeping. These options are then evaluated for their environmental advantage, technical feasibility and employee & employer accessibility. These evaluations lead to improvement

mainly into two different categories, which are housekeeping and input changes.

3.6 Remanufacture and Refurbishment

Actually before sending the product to recycling, the manufacturer has the option to see whether the product can be repaired or reconditioned by either substituting the parts of the item or by making cosmetic changes, so that it can be sold in the secondary market as reconditioned or remanufactured goods.

3.7 Green Distribution

Shalishali (2009) classified green distribution as green packaging and green logistics. The transport characteristics of the product are influenced by factors like size, shape and materials, which have an impact on distribution. To overcome these impacts, a better packaging along with rearranged loading patterns could be used to increase the space and reduce the amount of handling.

3.8 Green packaging

According to Ninlawan (2010), green packaging can be practised by using green packaging materials, promoting recycling & reuse programs and cooperate with the vendor to standardize the packaging.

3.9 Green logistics

Jiang (2008) defined green logistics as producing and distributing goods in a sustainable way and the activities include measuring the environmental impact of different distribution strategies, reduction in energy usage for logistic activities, reducing waste and managing its treatment. The system integrates with traffic and transportation, storage & delivery, management & supervision and information flow.

3.10 Reverse logistics

Rogers & Tibben –Lemke (1998) defined reverse logistics as the process of planning, implementing and controlling the efficient, cost effective flow of raw materials in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or disposal. All the activities that a company carries out to collect the used, damaged, unwanted or outdated products as well as packaging and shipping materials from the end user or reseller could be considered as reverse logistic activities. Once the product has been returned to the company, the firm has multiple options to choose like resell, sell via outlet, salvage, recondition, refurbish, remanufacture, reclaim materials, recycle or landfill.

3.11 Waste management of product and processes

Waste management is an effect directed approach towards nature because it tries to reduce the landfills and

incineration of waste materials (Shalishali 2009). The collection, transportation, composting, recycling and disposal along with regulating and monitoring form a solid waste management system. Reuse is an important method of handling waste. It promotes the use of something again in its original form for the same or different purpose. Recycling is the process of reprocessing the used material to make a new product through physical, chemical or biological method. Recovery is the use of processed recyclable material as feed stock for industrial activities from waste. The energy released from this waste is used for generating steam or electricity.

4. MOTIVES FOR GSCM

The GSCM can be practised in the organizations through several internal and external drivers. New Zealand Business Council for Sustainable Development described, in their practical guide for business: guide to sustainable supply chain (2003), that supply chain is mainly focussed on three areas, such as 1) Improving the performance of business's own operations 2) Ensuring that the goods and services provided by the suppliers are sustainable and working with suppliers increases the efficiency and competitiveness and 3) Working effectively with customers and sales channel to design sustainable products and services. On against the backdrop of these general trends, the companies mainly rely on the motivation factors, which are classified as primary and secondary motivations.

Primary Motivations mentioned are:

Internal motivations and possible effects	External Motivations and possible effects
Risk Management • Supply interruption • Long term risk to human and environment • Competitive advantage Regulatory stance • Desire to go beyond compliance • Suppliers knowingly or unknowingly provide problematic substances • Supplier non-compliance poses production risk	• Enhanced brand image • Corporate culture of forecasting trends and moving proactively • Potential for harm to public image for environmental concern • International Purchasing Restrictions • Ecolabeling and product take back gaining momentum • May drive the creation of system for collection • Frequently focussed on high profile brands, transport, disassembly or recycling • Customer pressure • Often appear in conjunction with a threat to brand image • Regularly focusing on high profile brands

Source:

Secondary Motivations, such as 1) Cost reduction as suppliers apply pollution prevention 2) Enhanced quality and 3) Increased motivation, can result from supplier participation in new product development.

5. ENVIRONMENTAL AND ECONOMIC BENEFITS OF GSCM

According to the study performed by Lefebvre et al. (2000) on SMEs in Canada, implementing green strategies into the organization can help in improving the organizational innovativeness i.e. product, process and managerial innovation can be improved. According to them, the organizational competitiveness (cost containment, liability management and export performance) can also be developed. Zhu et al. (2007) mentioned that EMS such as GSCM has a positive relationship on the organizational economic performance. Sangwan KS (2011) differentiated them into qualitative and quantitative benefits such as:

Qualitative Benefits	Quantitative benefits
- improved working condition - Better organisation in public - Improved staff morale - Enhanced customer loyalty/ satisfaction - Establishing or improving brand value - Lowered regulatory concerns - Increased market opportunities - Improved product performance - Decreased liabilities	- Waste related - Reduced waste handling cost - Lowered waste categorization cost - Reduced waste treatment cost - Reduced waste disposal cost - Reduced waste storage cost - Life cycle related - Lowered transportation cost - Decreased packaging cost - Lowered cost of production - Low maintenance cost - Reduced overall cost of organization

6. ORGANIZATIONAL PERFORMANCE

Performance is a measure for assessing the degree of a corporation's objective attainment (Daft, 1995). Corporations adopting GSCM practices may generate environmental and business performances (Walton, et al., 1998; Zhu and Cote, 2004). A green supply chain, for example, can improve environmental performance (reducing waste and emissions as well as increasing environmental commitment) and competitiveness (improving product quality, increasing efficiency, enhancing productivity and cutting cost), thereby further affecting the economic performance (new marketing opportunities and increasing product price, profit margin,

market share and sale volume; (Purba, 2002). According to Walton, et al. (1998), Zhu and Cote (2004) and Purba (2002), as well as other experts, organizational performance measure is considered to include both environmental and financial performance.

Hypothesis

Keeping the global scenario in mind and seeing the way our environment is being impacted as well as considering the insights obtained from the extant literature, we feel GSCM practices are in a critical position to influence a country's carbon footprint. There exists a vast scope in developing countries, such as in India to adopt GSCM practices and thereby achieve organizational excellence. Small scale and medium scale manufacturing industries in India contributes largely to, and play a vital role in, the Indian economy. Therefore, we have laid our focus in assessing GSCM practices of Indian SMEs and have further hypothesised as follows:

H1: ENVIRONMENTAL PERFORMANCE HAS A POSITIVE RELATIONSHIP WITH GSCM PRACTICES IN SME MANUFACTURING FIRMS.

H1a: Reduction in business wastage improves environmental performance of manufacturing firms.

H1b: Environmental emissions directly impact environmental performance of manufacturing firms.

H1c: A firm's green image positively influences environmental performance.

H1d: Government involvement in GSC initiatives has a positive influence on willingness of SMEs to participate in GSC initiatives, thereby promoting environmental performance.

Construct definition: Business wastages are considered as hazardous & toxic material output, solid & liquid wastes, total flow quantity of scrap and percentage of materials remanufactured. Emissions are air emission and energy consumption. Green image of a company is enhanced by participating/organizing fairs or symposiums related to environmentally conscious manufacturing. The above hypotheses are proposed, based on the findings of (Zhu and Sarkis, 2006), (Hall, 2000), (Sarkis, 1998), (Hui, et al., 2001), (Gottberg, et al., 2006), (Hervani, et al., 2005), (Sarkar and Mohapatra, 2006), (Sheth and Sharma, 1997; Cannon and Homburg, 2001), (Doonan, et al., 2005), (Papadopoulos and Giama, 2007), (Tsoufas and Pappis, 2006), (Carter and Carter, 1998; Walker et al., 2008; Large and Thomsen, 2011; Buyukozkan and Cifci, 2012), (Lu et al., 2007; Hitchcock, 2012).

H2: GSCM practices have a positive influence on economic performance of SME manufacturing firms.

H2a: Environmental cost and efficiency have a direct and a positive relationship with economic performance.

H2b: Environmental revenues directly influence the economic performance.

H2c: Governmental regulations directly influence the economic performance.

Construct definition: Environmental cost and efficiency are cost of purchasing environmentally friendly products, cost of scrap/ rework, disposal cost, operating expenses, overhead expenses, fines & penalties and manufacturing cost. Environmental revenues are revenues from green products, recycling revenues and cost avoidance from environmental action. The above hypotheses are proposed, based on the findings of (Zhu et al., 2005; Azevedo et al., 2011; Green et al., 2012), Kumar et al. (2012), Koh et al. (2012), (Carter and Carter, 1998; Walker et al., 2008; Large and Thomsen, 2011; Buyukozkan and Cifci, 2012), (Lu et al., 2007; Hitchcock, 2012), Rajkumari Mittal., S. g. (2013).

H3: GSCM practices have a positive influence on operational performance of SME manufacturing firms

H3a: Customer satisfaction has a positive influence on operational performance.

H3b: Product delivery & time directly and positively impacts operational performance.

H3c: Inventory levels have a direct relationship with operational performance.

H3d: Product quality positively influences the operational performance

Construct definition: Customer satisfaction deals with after sales service efficiency, out of stock ratio and rates of customer complaints. Product delivery and time are delivery reliability, on time delivery, responsiveness to urgent deliveries, cycle time and delivery lead time. Inventory levels are level of safety stocks and order to ship. Product quality is customer reject rate and inplant defect fall out rate. The above hypotheses are proposed, based on the findings of (Papadopoulos and Giama, 2007), (Sarkis, 2003), (Tsoufas and Pappis, 2006), Buyukozkan and Cifci (2012), Sangwan K S (2011), Zhu, Sarkis, Kee-hung Lai, (2007), Rajkumari Mittal., S. g. (2013).

H4: Government initiatives impacts relationship between GSCM practices and business performance

Government involvement in GSC initiatives include direct technical and financial support, indirect encouragement with tax cut incentives and development of infrastructure for environmentally friendly industrial complexes (Su- Yol Lee). Globally, Governments are more involved in GSC practices as more emphasis is now laid on life cycle of products than pollution controls at manufacturing plants. Noci and Vergandi (1999) claimed that governmental support and regulations are more important triggers for environmental innovations in SMEs. R P Mohanty (2014)

reported that the external pressures of government regulations lead to GSCM practices.

7. CONCLUSION

It has been found from the extant literature that the major barriers to GSCM implementation is the unwillingness to change and the threat of incurring huge costs without getting proper returns. In this specific context, the proposed hypotheses are expected to help us in the measurement of the performance of GSCM practices in India. It shall additionally throw light on the level of maturity of GSCM practices and setting up of environmental goals. Thus, GSCM implementation can be eased by establishing clearly and communicating the benefits, cost and risk reduction to the top management or decision makers of SMEs in India.

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Impact of Goods and Services Tax (GST) on Supply Chain in India

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Abstract : Companies planned their supply chain to save fiscal costs incurred in supply chain, hence as of now most of the companies having a tendency to locate their warehouses in each state. Hence they are supposed to pay tax as per state taxation policy when they move goods, and tax will not be refunded when you sell item from state to state, due to this reason companies used to set-up their own warehouses in each state to take the cost leverage. This is post GST scenario but implementation of GST companies will get tax credit even they move their goods from one state to another state. The GST law 2017 is simultaneously address both issues of the dual governance structure of the state and central bodies which leads to inefficiencies and many loopholes in the system. Also, the comprehensive effect of the multi layered taxes leads to higher taxes. The implementation of GST from 1 July 2017 will make the supply chain more efficient & effective and at the same time Logistics, outsourcing, distribution and warehousing is going to see a major transformation near future.

Keywords: Goods services and tax, Supply Chain, Logistics

1. INTRODUCTION

GOODS AND SERVICES TAX:

Due to complexities of the old tax system in India in near future the implementation of GST seems to be the biggest game changer for Indian taxation system. The old taxation system includes many taxes, many outdated rules and many legislations that can take up too much time and effort. Goods and services tax is an indirect tax this tax is imposed on manufacturing of product, sale of any goods and consumption of goods and services provided by service industry. This new tax system will replace the tax collected by the central and state governments. In this system tax collected during the purchase or sale of goods is independent of the state where the purchase or sale takes place.

The tax structure proposed by GST concile and the government pass the GST Bill or The Constitution (One Hundred and Twenty Second Amendment) Bill from the both houses of parliament. The tax rate under GST are 0 %, 5 %, 12 %, 18 % and 28 % this would be lower, however, there would be an increase in the number of assesses which come under the umbrella of GST. The increased number of assesses is expected to make up for the reduced tax and the overall tax collection is expected to increase but at the same time initially implementation create some problems to the

businesses. Some of the best GST systems across the world like Singapore and New Zealand use single GST, but India has opted for a dual GST model. The change in tax structure is expected to have a huge impact in supply chain in India.

2. SUPPLY CHAIN MANAGEMENT

Supply Chain Management Means -To managing efficiently the flow of goods and services and to control the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. Now a days E - Commerce is fast growing market, The management of supply chain is totally mandatory for all organization. Without managing supply chain efficiently and effectively you have no idea to start or grow any business. Supply Chain Management (SCM) or commonly we can say Logistics is the crucial part of any business related to goods or services.

Supply chain is not only take care of material, information and finance that move through the process, from supplier to manufacturer to whole seller to retailer to customer but its ultimate aim to achieve achieve JIT (Just-in-time), inventory optimization, reduce cost and provide prompt service to the customer so as to increase profit.

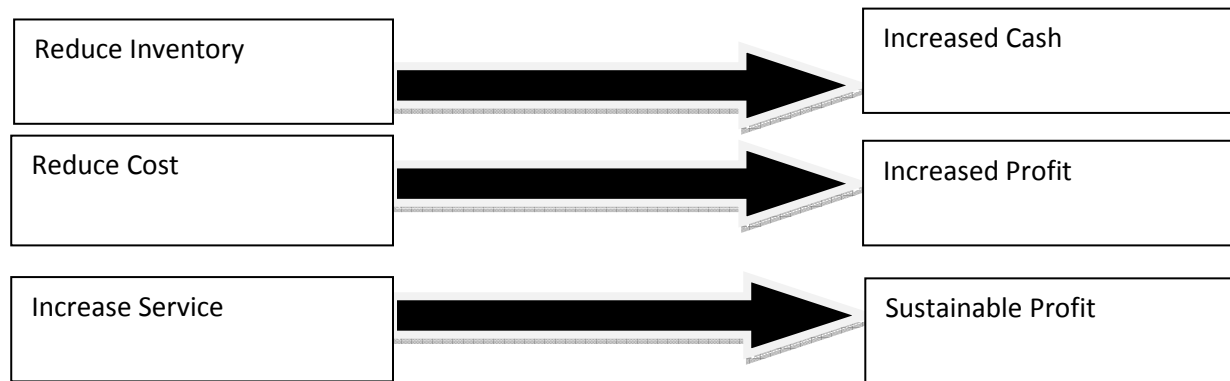


Fig. 1. Impact of Supply Chain

Supply chain management involves the flow of materials between various parties that is-

1. Supplier to Manufacturer.
2. Manufacturer to Wholesaler.
3. Wholesaler to Retailer.
4. Retailer to Consumer.

There are 3 main flows of the supply chain: –

1. Product Flow.
2. Information Flow.
3. Finances Flow.

Supply chain is a complete network which creates the link between the producer and the customers. There is plenty of scope in supply chain management field especially in India. You would be surprise to know that India's inefficient supply chain results in an approximate loss of \$65bn per year (data from 2016). The statics show that around 13 percent of GDP in india constitute by supply chain costs which is more than 1.5 times of the percentage of developed countries. In the US, supply chain costs amount to 9 percent of the GDP. 65% of logistics in India moves by road and time spent at interstate check posts due to difference in taxes between states accounts to idle time (60% of total journey time) which will get eliminated in GST regime. Hence, transport time would reduce by 30-40% and transport costs by 20-30% leading to fall in prices by 3-4%.

3. IMPACT OF GST ON SUPPLY CHAIN MANAGEMENT

Supply chain is not only constitute the material, information and finance that move through the processes, from supplier to manufacturer to whole seller to retailer to customer but its ultimate aim is to achieve JIT (Just-in-time), inventory

optimization and reduce cost. In present system there are an array of taxes like excise duty, VAT, CST, etc. which levied at each level and added to the whole value known as Tax Cascading. GST will make it simpler and easier by contributing to a lower cost of production as tax at each level will be charged only on the value addition to an item. The major drawback of present indirect tax regime is the absence of tax credit will be eliminating by allowing unrestrictive tax credit under GST.

Before implementation of GST the thinking of industries is to keep warehouses and C&F agents at every state to avoid tax credit unavailability but post GST regime they rethink and this new system will provide industries the freedom to restructure their supply chain network. The new GST regime will once again better the situation by unifying the Indian market and facilitating a smoother flow of goods within the country. Even though border checkpoints may still exist for some time, the minor scrutiny at these checkpoints will greatly reduce transport hassles.

Goods and Service Tax is an attempt by our government to simplify and streamline our taxes, facilitate market growth and increase the revenue for our government by increasing its tax base.

The supply chain structure is gretely influenced by differential taxes based on geographical location. By eliminating multiple state taxes, the logistics companies are optimistic and consolidate their warehouses instead of maintaining one in each state to avoid central tax. This in effect brings the overall cost of the product down as the inventory cost and inventory carrying cost down. This frankly affects the final cost of the product brings the selling price down. The cost saved by the companies as a result of GST can be used to invest further to improve serviceability. The following are the major driving Factors of Supply Chain:

- Sale goods within a state

- Minimize tax liability.
- Procurement of Raw Materials, Packing Material, Consumables in a most tax effective manner to reduce Landed Cost
- Maximize Post Tax Return
- Maximize Value Addition in Supply Chain

After GST implementation, the design of the supply chain depends on customer service and logistics cost. It also offers flexibility into demand and supply. GST would also facilitate firms to increase the accuracy of the forecast. Small and medium size warehouses can also be merged into one bigger warehouse and by this companies can optimize their space requirement. Before GST trucks are idle for about 40% of the total travel time due to Central Sales Tax/Octroi payment. But due to GST implementation the time taken at various check posts while transporting goods will come down, which will, in turn, reduce costs and customers and logistics companies will get goods at shorter time which makes industries more efficient and profitable in the near future. Supply will also be able to match demand to a large extent.

The following are the benefits to the industry post GST implementation:

- Interstate transactions.
- Negotiation of price
- Better quality
- Improved forecasting
- Optimum inventory management
- Better trade-off between cost and customer service
- Capacity expansion
- Manufacturing flexibility
- It matches the demand and supply flexibility.
- Avoid unnecessary stock movement through states..

4. CONCLUSION

The implementation of GST in India will definitely make supply chains more efficient and effective from the current scenario, with the help of these industries having freedom to redesign and rebuild their supply chain network. Post GST, India would become a uniform, common market for Goods and services, the tax barriers and amongst the state borders eliminated. By reviewing the complete cycle of supply chain the impact of GST would lead to re-engineering of warehouse strategy by diverse manufacturers and key companies. Before GST the decisions on location of warehouses will be driven by tax considerations, interstate transactions. Warehousing decisions will from this time forth be driven by considerations like location of major customers/market and optimization of goods movement. Since any supply would be taxed, branch transfers would get discouraged leading to optimization of transport. Elimination of statutory forms (C-Form, F-Form, E1-E2 etc.) would reduce the requirement for scrutiny at state borders. After GST implementation, the design of the supply chain will be based on customer service and logistics cost. As the next level of logistics is evolving in India and the corresponding regulatory policies have to be taken care well ahead of the GST introduction to have a positive and predictable impact.

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KPMG GST Report -2011

Advanced Planning Systems for Supply Chain Transformation: A Case of Indian CPG Industries

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Abstract: Companies are now seeking how to integrate decisions across supply chain functions, across geographically dispersed facilities and all time visualization of data “The fact based supply chain is crucial .the essence of fact-based supply chain management is integrated with advanced planning systems and supply chain process for better planning and control .which has three important dimension .

The first dimension is functional integration involving decisions about purchasing, manufacturing and distribution activities within the company and between the company its suppliers and customers

1. Geographical integration of these functions across physical facilities located one or several countries.
2. Integration of strategic, tactical and operational supply chain decisions.
3. Today's supply chains crave a solution that combines an accurate representation of business uncertainties, an adaptive inventory optimization, and a near-real-time status of inventories and orders.

The purpose of this paper is to propose that Supply Chain Transformation through Digitization of Demand Planning and S&OP Process for CPG Organizations, in global supply chain complexities is a result of the strategic alignment between demand planning and S&OP process to achieve supply chain strategies. The purpose of the study is to explore what potential benefits could be achieved by using APS(Advance Planning System) systems in the supply chain process, consisting of benefits divided into three types of benefits; **decision support, planning efficiency.**

The study indicated that the decision support benefit “**visualization of information**” has been underestimated in organisations by planners. The study analyses that the benefits perceived in the different S&OP activities, in the demand planning sub-process, perceived that the use of S&OP resulted in a reliable demand plan, good knowledge about the supply chain and made the planning activities more enjoyable.

The companies set up S&OP on a stock keeping unit (SKU) level, with the possibility of re-planning and a flexible planning horizon, thus differing from what has generally been suggested by various experts. In addition, the companies are aligning the inputs, activities, and outcomes of the S&OP process to the planning environment. Particularly important environmental contingencies are uncertainty connected to demand and supply, frequent new product launches, and production network complexity. Product-related variables have a higher impact on the S&OP design, planning frequency: these needs to be able to consider the demand and capacity uncertainties, as well as take into consideration supply uncertainty.

1. RESEARCH AIMS AND OBJECTIVES

The objectives of this research is to understand the real essence of supply chain integration and digitization of demand planning & S&OP process, I aim to assess the effect of demand Planning & S&OP process integration is beneficial to CPG industries supply chain performance.

51 As a result, the following research Aims and objectives have been identified

In CPG originations 90% of the cost is uncontrollable: due to hefty fluctuation in commodity and Raw Material prices with very little control, organization has to focus on 10% of operating cost which is the only controllable component within entire operation cost structure.

However small and about 10% is the key element for Market Differentiation, Thin margin business and profitability are through the volume sales in CPG industry.

Sales Growth and Increase in brands and SKU, s every month is further creating complexity in business planning which is existent due to insufficient and Manual Processes, Multi SKU, s Management across large number of locations (in production as well as Storage Space) is a big challenge.

Seasonality and Sourcing uncertainly leads to complexity in managing limited warehousing capacity and hence the difficulty in managing customer service at lowest possible supply chain costs, Customers are demanding the availability of goods in the convenient shopping and treating as commodity.

2. CPG INDUSTRY

The CPG industry typically thin margin and profitability is mainly through attaining volumes and other important characteristic is 90% of the cost is uncontrollable due to hefty fluctuation in commodity and raw material prices with very little control, organization has to focus on 10% of operating cost i.e supply chain costs, branding which is the only controllable component within entire operation cost structure.

The branding typically relates to growth plans of company have left only option to control the supply chain costs. By using the advanced supply chain planning methods these can be controllable to some extent.

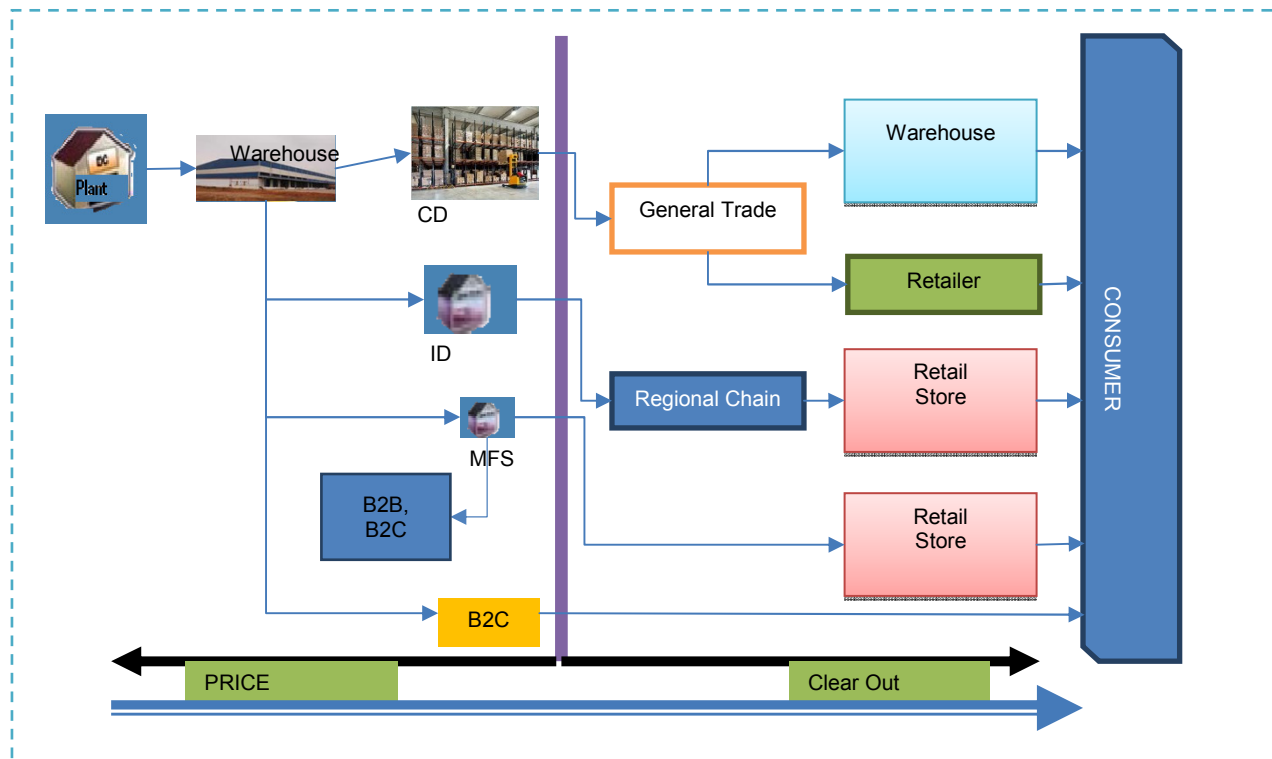
The key challenge of any supply chain is make sure that right SKU should be available at right place, seasonality, sales growth and Increase in brands and SKU, s every

month is further creating complexities in supply chain. As supply chain network is large and hence manual planning and process becomes challenge. The demand fluctuations is also leads to complexity in supply chain and managing limited capacity of warehousing is also becomes difficulty which effects customer services level at lowest possible supply chain may also lead to loss of sale.

Customers are demanding the availability of goods in the convenient shopping and treating as commodity hence CPG supply chain as to deliver right SKU at right place and supply chain costs are should be with in planned costs.

3. CPG SUPPLY CHAIN

Distribution is the main driver of supply and is managed through warehouses and point of sales spread all over the country. Every warehouse handles all the SKU's to serve the market demand.



Source: Adapted from JDA network Planning -2014

4. LOGISTICS

Logistics oversees the actual transportation of the goods from one point to another. Every organization does not have own or dedicated transportation but has an empaneled or preferred Logistics Service providers with whom it has long term association. The cost depends on actual transaction and vehicles arrival at manufacturing locations.

The commodities industries like oil which imports nearly 60% of raw materials and mainly processing plants located close to port. The advantage of port based locations is that the vehicles come loaded into the port and normally do not have a return load. So the price will be lower than the dedicated vehicles. However at some ports when imports are high the situation might be reversed. But this also limits the availability because the incoming vehicles have specific

and limited destinations. The frequency of incoming vehicles for a specific destination also varies and hence vehicles may not be available on daily basis to all given location.

The vehicle availability to certain difficult destinations may not be there as per logistics requirement. The availability is also in lumps i.e. when the vehicles arrive at a port they arrive in lots.

While the problem with hinter land plants is that the in-bound and out-bound vehicles market is not mature and hence the availability is not certain and has to mostly depend on hiring vehicles from local transporters. These transporters always look for return loads and hence the availability may be delayed till return load is available. Since these hinterland plants mostly supply within the state the return load from such destinations is limited. This leads to higher cost than port based plants.

5. WHY ORGANIZATIONS ADVANCED PLANNING SYSTEMS AND PROCESS

Because of dynamic logistics contracts costs the locations of warehouses/ storage points becomes very crucial. Once warehouse locations fixed for time period then orders from markets are random hence it requires Advanced Planning tools for planning and process to execute the plan. The Advance Planning System (tools and process) for supply chain should support decision support and, planning efficiency.

6. ADVANCED PLANNING SYSTEMS

The Advanced Planning Systems (APS) will automate and enable various strategic, tactical and operational plans/decisions in the entire supply chain. The strategic, tactical and operational plans/decisions will be driven by the intelligence derived from total analysis at various stages in the supply chain – production, procurement, primary freight, storage, secondary freight and distribution. The APS will drive the intelligence with the optimization/analytical techniques and scope of applying these techniques in the supply chain is as follows:

- 1) Strategic optimization for locations and capacities of production, packaging facilities, new warehouses depots, and new markets.
- 2) Integrated tactical optimization for plant to warehouse logistics allocations including stock transfers and direct dispatches from plants to destinations (movement of finished and packed products), and procurement from suppliers to plants (movement of major raw materials and fuel).
- 3) Production scheduling for different SKU at each plant – lot sizes and sequences of different products on equipment's/production units.

- 4) Inventory stocking and replenishments at storage points – warehouse (for finished products) and plants (for major raw materials).
- 5) Transport scheduling and routing – vehicle fleet-mix at plants (for primary freight) and at warehouses (for secondary freight); daily/weekly dispatch loads and routes (for primary freight) and daily routes (for secondary distribution) including FTLs, PTLs and Milkruns.
- 6) Forecasting of demands (sales) of SKUs in markets (destinations) over short-term, medium-term and long-term – useful for the decision support models mentioned in points 1-5 above.
- 7) Real-time tracking and management of logistics and distribution from plants to markets or warehouses to markets – Reporting status of operations; Confirming tentative arrivals of goods to customers; Re-allocation, re-scheduling and re-routing in events of contingency.

The advanced planning systems will aims to cover the analysis for all the above decisions throughout the any supply chain, and their implementation, tracking and reporting. These systems will work at various levels of organizational hierarchy, at different stages in supply chain, and at different rolling time frames. However, they will work in sync with each other in an integrated manner. They will draw input data from a transactions system (I.e SAP etc) and ability to push decisions / outputs to the transaction system.

Thus, the advanced planning system will contain two components:

- A) **Decision Support System (DSS):** This will comprise all the advanced tools and models and the related data.
- B) **IT System:** This will comprise the relevant hardware, data (BI) warehouse and software interface for managing the inputs and outputs of the DSS.

The IT system will manage two major functionalities:

- i) Managing input data for DSS/ advanced models:

Input data will come from different sources ERP (SAP) system, information from GPS and RFID sensors, and custom developed interface for user-defined parameters for the models. The IT system will feed these data into the DSS/optimization models.

- ii) Managing outputs from DSS/optimization models:

The outputs of DSS/optimization models will be the recommended decisions/plans and related scenario analyses. The IT system will generate such reports and transmit them to relevant decision-making users/authorities

via dashboards. Different types of reports will be sent to different users as outlined in the next section “Description of Models”. This reporting hierarchy will be defined in the IT system.

The following figure depicts a broad architecture of advanced planning systems. The ‘Input Layer’ will gather all relevant data from various sources in supplychain and

process and push the data into the ‘DSS Layer’. The ‘DSS Layer’ will take in that data and perform relevant optimization/analytical calculations and generate results for various plans and schedules in the supply chain. These results will be pushed into the ‘Presentation Layer’ which will process them and send relevant reports to various users in organization.

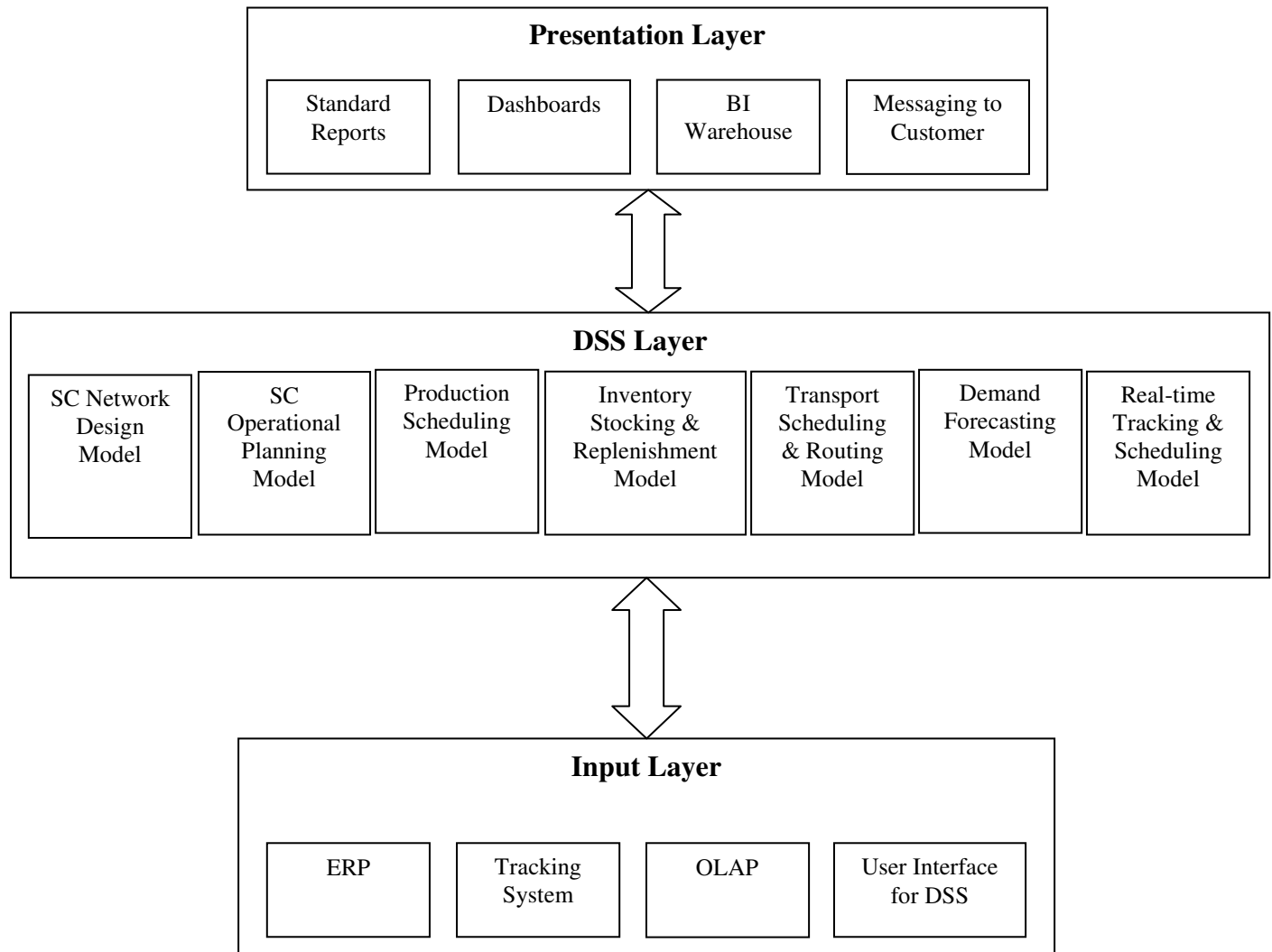


Fig. 1. Advanced Planning Systems Architecture.

Advanced planning systems have the potential to create an accelerated business value but organization need understand implementation issues advanced planning systems

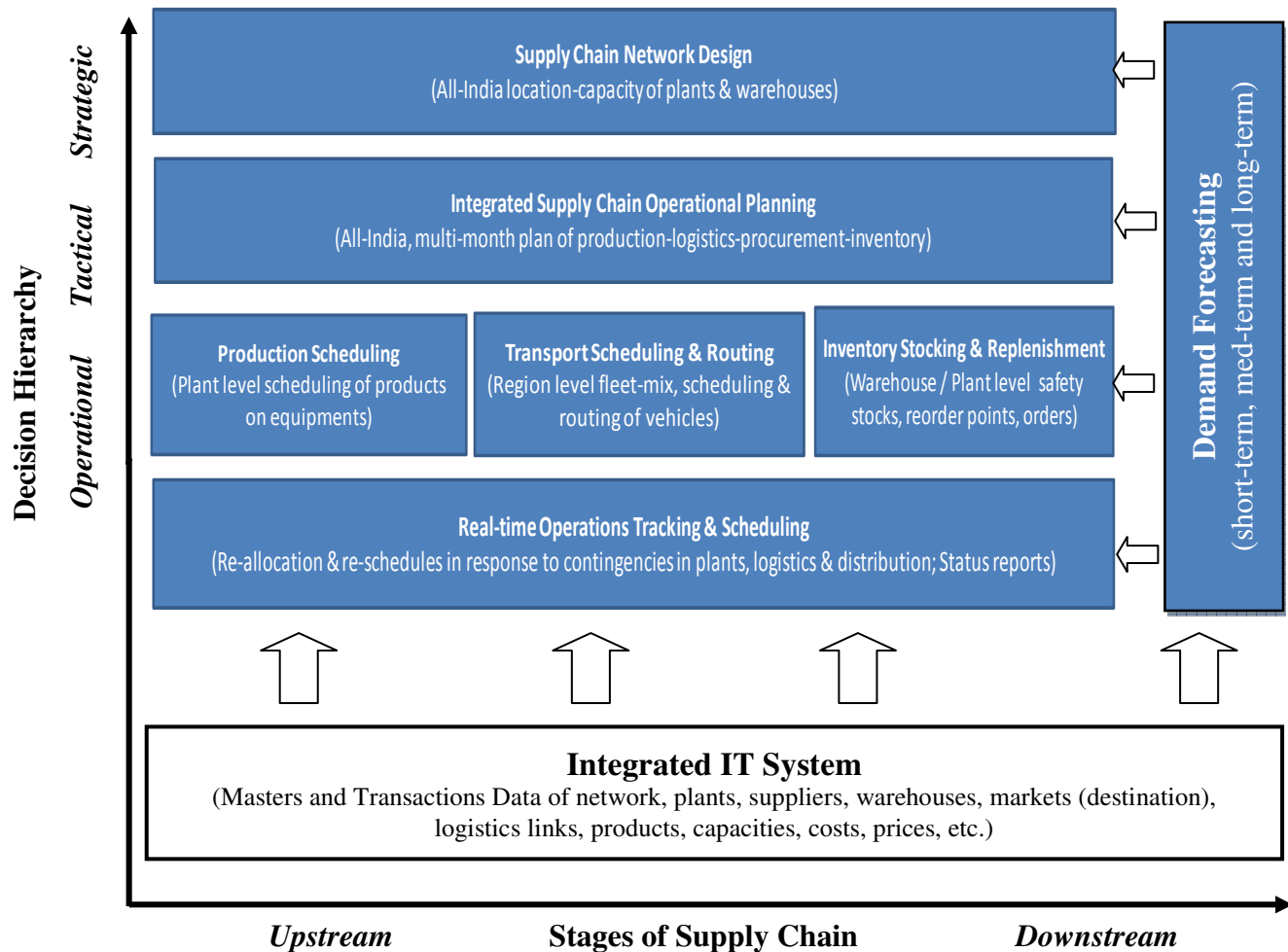


Fig. 2. Advanced Planning Systems for supply chain planning.

7. DESCRIPTION OF MODELS IN THE DECISION SUPPORT SYSTEM (DSS)

The following boxes provide a brief description of each optimization/analytical model in the proposed DSS of the Integrated Portal. Each box indicates the intended users of the model, objectives of optimization, time frame (rolling horizon), and key data inputs and key output reports.

Supply Chain Network Design	
Users: Top management / Heads of supply chain, logistics, production [Corporate Office]	
Objectives: Minimize all-India/regional network cost; Meet growth & service level targets	
Decision time frame: Few years, 1 year, 6 months	
Inputs •Goals of growth and expansion •Existing & candidate locations/capacities of plants, warehouses •Costs of capital, production, raw material, transport, etc.	Outputs •Optimal locations/capacities of plants, warehouses •‘What-if’ analysis for scenarios of growth, locations, tax structures •KPIs: costs, service levels, etc.

Integrated Supply Chain Operational Planning	
Users: Managers of logistics, production, procurement [Corporate Office / Plants / Regional Offices]	
Objectives: Maximize all-India/regional contribution; Minimize total cost-to-serve; Meet demands	
Decision time frame: 12 months, 1 month, 1 week	
Inputs •Existing locations/capacities of plants, warehouses, transport links •Variable costs of production, raw material, transport, taxes, etc. •Upper/lower bounds on logistics flows, market shares, etc.	Outputs •Optimal plant-warehouse-market allocations •Optimal plan of production, route-modes, procurement, inventory •KPIs: contribution margins, costs, service levels, bottlenecks, etc.

Production Scheduling	
Users: Managers of production [Plants]	
Objectives: Minimize plant level variable cost; Maximize utilization; Meet production plans	
Decision time frame: 7-14 days, 1 day, 1 shift, 1 hour	
Inputs •Weekly / monthly production plans •Production units/equipments, capacity, availability, changeovers •Costs of raw material, production, packaging, etc.	Outputs •Optimal schedules & sequence of product lots on equipments •Contingency re-scheduling – in events of break-down, rush orders •KPIs: plant level costs, utilization, etc.

Inventory Stocking & Replenishment	
Users: Managers of logistics & production [Plants & Warehouses]	
Objectives: Meet service level targets at plants and warehouses	
Decision time frame: 7-14 days, 1 day	
Inputs •Closing stocks; Weekly / monthly production and logistics plans •Service level targets for finished products and raw materials •Constraints of stock availability, funds/credit, vehicle loading, etc.	Outputs •Safety stock levels and reorder points at plants & warehouses •Orders generated from warehouses & plants •KPIs: service levels (stock-outs), deviations, inventory cost, etc.

Transport Scheduling & Routing	
Users: Managers of logistics and sales [Regional Offices; Area Offices; Sales Units; Warehouses]	
Objectives: Meet service level targets (demands); Minimize transport cost in a region	
Decision time frame: 7-14 days, 1 day	
Inputs •Weekly production and logistics plans and service level targets •Costs of primary freight, secondary freight, handling, etc. •Constraints of vehicle availability, routes/network, etc.	Outputs •Optimal vehicle/fleet-mix at plants and warehouses •Primary freight schedules; Secondary routes – FTL/Milkrun/PTL •KPIs: on-time deliveries, vehicle utilization, transport cost, etc.

Demand (Sales) Forecasting	
Users: Managers of sales & logistics [Sales Units & Warehouses]	
Objectives: Forecast sales (demand) and meet sales targets	
Decision time frame: short-term (1-7 days), med-term (1-12 months), long-term (1-2 years)	
Inputs •Daily sales in the past 3 months (SKU-Destination wise) •Last two years' monthly sales to capture seasonality •Other causal factors and expert/user inputs of trends & targets	Outputs •Short-term sales forecasts (next 1-7 days) •Med-term sales forecasts (next 1-12 months) •Long-term industry/market and sales forecasts (1-2 years)

Real-time Operations Tracking & Scheduling	
Users: Managers of logistics, plants and sales [Plants; Regional Offices; Sales Units; Warehouses]	
Objectives: Respond to real-time contingencies; Meet service level & other priorities; Minimize cost	
Decision time frame: Real-time (1 day, 1 hour)	
Inputs •Day's production and logistics status: work-in-process & schedules in plants, primary freight, secondary freight (distribution) •Contingency events: e.g. stock-outs, rush demands, break-downs, etc. •Constraints of vehicle availability, on-going schedules, resources, etc.	Outputs •Re-allocations and re-schedules in response to contingencies: in plants, primary freight, secondary freight (distribution) •Reports of current status of production and logistics •KPIs: on-time deliveries, delays, costs, etc.

8. PROCESS

The DSS will work at different hierarchy level and different time horizons and order execution is at lowest level hence planning process need to design for seamless integration of DSS decisions. These process also support organisation to setup a cross-functional decision process which reconciles conflicting business plans, links strategic planning and operational planning, and aligns company resources to deliver one enterprise plans.

The key process demand planning process, supply side planning process, stock replenishment process, order execution process etc. The most important aspect of advanced planning system the decisions should seem lessly flow from one department to other department and facilitate the collaborative planning of production, sales and logistics departments.

For many enterprises today challenges are increasing:

- Managing a more complex supply chain – maintaining visibility and control.
- Achieving greater responsiveness and agility – respond quickly to changing market conditions & new business opportunities seamlessly.
- Enabling growth and delivering value – beyond cost control, delivering business value and driving profitability.
- Service Improvement & Higher Delivery Expectations – enhanced quality of service to end users.-

- Risk Reduction – business continuity & security of supply Companies which are able to master these challenges effectively are more equipped to get ahead of competition and quickly adapt to new market realities by delivering new models of Supply Chain operation, achieving true flexibility and responsiveness, and more strategically targeted performance improvement

The Sales & Operations Planning (S&OP) and demand planning are emerging best process in FMCG industry and same process can also be implemented in CPG industry.

S&OP Process

Sales & Operations Planning (S&OP) is a set of decision-making processes to:

- Balance demand and supply
- Integrate financial planning and operational planning
- Link high-level strategic plans with day-to-day operations.

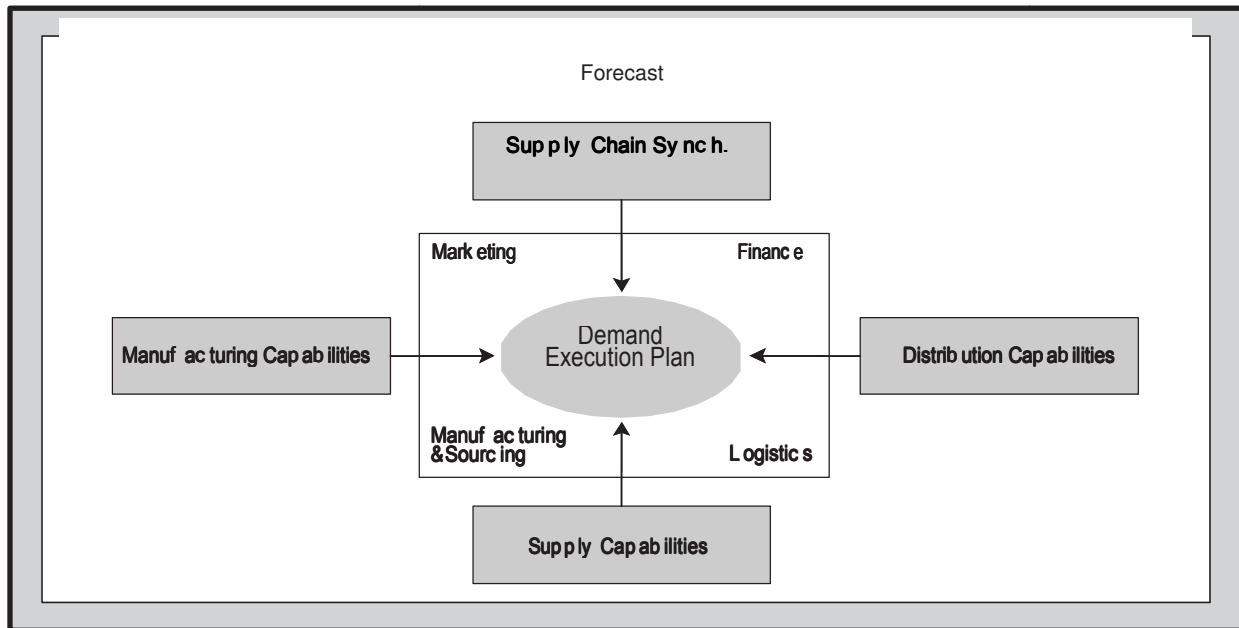
9. DEMAND PLANNING

The demand planning process streamlines the efforts of the sales, marketing, finance and operations departments to match demand and supply contributes to the appropriate use of resources in the fulfillment of customer demand.

Demand planning and forecasts enable the manufacturing department to plan production to meet customer requirements. The forecasts also support the purchasing

department's efforts to correlate deliveries of materials and supplies with production schedules. In turn, a forecast also alerts finance to the level of investment in plant, equipment and inventory required to meet demand as well as the budgets to be created to manage the business. The demand

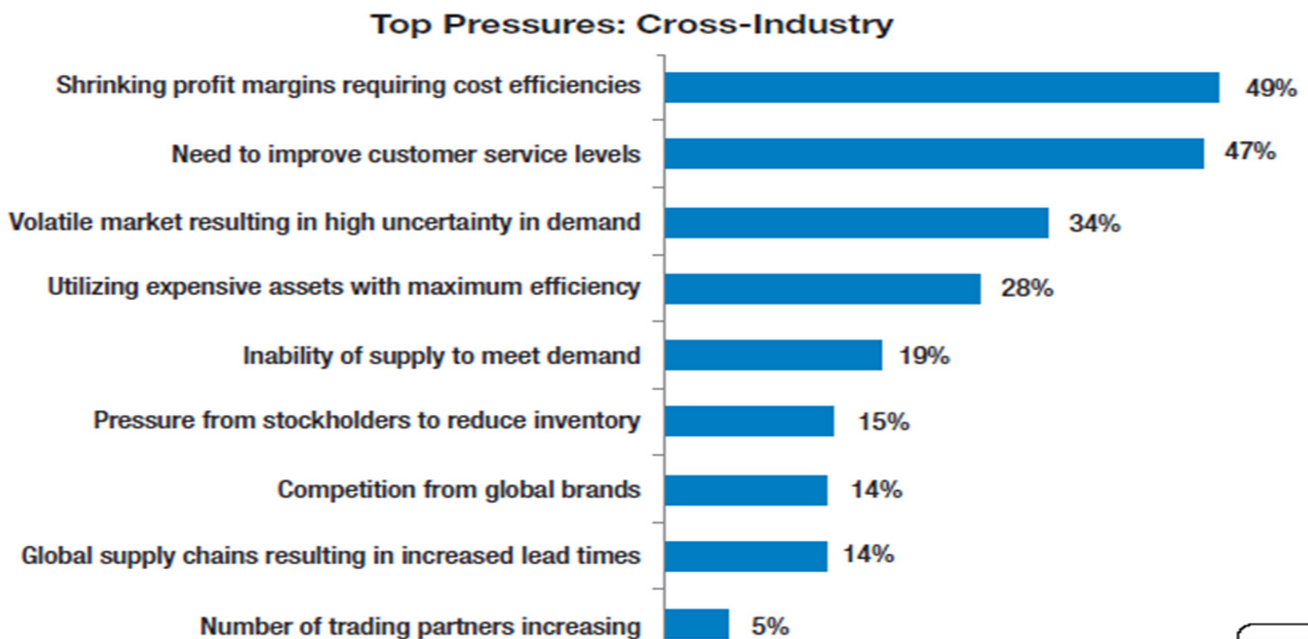
forecasts also affect the personnel department's hiring and training decisions and the marketing department's assignment of resources to particular product groups or marketing campaigns.



Supply Chain –Synchronization Model

Source- *The International Journal of Logistics Management*, Volume 13, November, 2002

10. WHY ORGANIZATIONS NEED DEMAND PLANNING AND S&OP PROCESS



Source: Adapted from Gartner Magic quadrant on demand Planning -2014

Globalization in the digital world means that the supply chain — efficiently moving products and services from one place to another — needs to be a core competency of every organization. Companies need to think about how they can create greater efficiencies in their global supply chains, while remaining nimble enough to respond to new opportunities in emerging markets and meet customers' complex demands. Technology can help streamline costs, but it can also be a vehicle for opening up new growth avenues, managing supplier risk, and efficiently sourcing materials from partners located around the world. Mobility and social media platforms are also influencing customers' expectations and putting power in their hands. As a result, businesses are feeling heightened pressure to deliver products and services in a timely, customizable way. This shift is influencing how companies interact with partners and suppliers.

(Source adopted from -Chain-link Research - 2015)

These trends are just as much opportunities for transformation as they are challenges, but companies need to think about their response strategically. They must adapt their structures to be more flexible and responsive, balancing cost controls with the need to maintain an integrated view of the supply chain across businesses and geographies. Given the complexities of global supply chains, organizations should take an incremental approach, first tackling a key process, division, or business unit that has the best likelihood of delivering the greatest value. For some companies, this might mean re-evaluating their sales and operations (S&OP) planning processes, leveraging in-memory solutions such as SAP HANA to make S&OP more of a strategic cross-functional discipline that is better aligned with business goals. Organizations should also consider how they can take advantage of cloud solutions like the cloud version of SAP Sales and Operations Planning to enhance their ability to collaborate internally and externally with partners and customers to create efficiencies, facilitate better customer service, and increase sales while controlling costs. Piloting such a solution may be the quickest way to get started on the path to technology enablement of these objectives.

Companies need to create greater efficiencies in their global supply chains, while remaining nimble enough to respond to new opportunities and meet customer demands.

The goal of many companies is integrated business planning. While integrated business planning lacks a common definition in the market, the most successful companies focus on the integration of process versus the integration of numbers. For example, in a mature company, the focus is agreement on a common plan, not a one-number forecast. There is a focus on the consideration of inputs into budget refinement, but the S&OP plan is seldom

constrained by the budget. Tight integration of the financial budget to the S&OP planning process is a recipe for disaster.

Leaders in this industry use sales and operations planning to determine effective promotion strategies, sense consumption through store clusters and point-of-sale (POS) data from vendor-managed inventory (VMI), and time new product launch activities by account. They identify S&OP as a key process to improve time to market for new product launch activities and as a means to align cross-functional teams on market opportunities. While CP companies were early leaders in the use of supply chain planning technologies, they lag other industries on the development of demand-driven S&OP processes. The primary demand-shaping mechanism is trade promotion activities.

11. CONCLUSION

APS are identified as potential support tools for managing complex SCM problems and as means for supply chain integration. This paper fills some of the knowledge gaps about how this could be done and the perceived effects of using APS, focusing on the strategic and tactical planning levels. Three explorative case studies show how APS can enhance SCM in various situations. Noteworthy is that all three cases are centred on the software use of a so-called SCP module, but the module is used on different planning levels addressing different problems.

Despite great progress in modelling and solution capabilities there are still many areas for improvements and for future research in SCM and AP. While the issues facing an inter-organizational SC are mainly addressed in research areas associated with the integration of individual organizations, our knowledge regarding process orientation and advanced planning across company borders is still in its infancy (Croom et al., 2000). As we have pointed out not only the underlying mathematics is concerned but also interdisciplinary research incorporating computer science, accounting and organizational theory,

In an effort to improve organisation competitive position in a rapidly changing marketplace, many companies have replaced their traditional supply chains with extended and advance supply chain networks built on a foundation of supply chain collaboration. These extended networks require the use of decision support tools and technologies to improve both operating efficiencies and customer service, but many companies have struggled to realize the expected benefits of these tools and the increased collaboration. This article recommends that companies adopt an integrated strategy of people, processes, and technology to achieve their competitive supply chain goals. Our recommendation is backed by the results of a survey we conducted of senior level practitioners concerning the importance and challenges of supply chain collaboration. The article

concludes with a set of managerial recommendations to improve a company's collaborative efforts within its supply chain.

The relationships between APS, planning organization and planning effects are thus obvious in these cases. Several positive effects of using APS as support for global SCP on strategic and tactical levels were identified, but the research conducted here also identifies and motivates several future research areas about the appropriateness and performance of APS usage.

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Reverse Logistics Facilities Network Configuration for Rubber and PET Products: An Industrial Case Study

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Abstract: In the present work, key reverse supply chain constituents contributing to sector-specific network have been examined through industrial survey for both types of product returns: end-of-life; and end-of-economic use. Further, the determination of the number and location of different facilities like collection centers, re-manufacturing centers, disassembly centers, recycling centers, disposal centers is demonstrated through real-field data of returns-flow and transportation costs of the products, and also for the intra-stage quantity-flow between facilities in the reverse supply chain.

An industrial survey of the rubber and PET (Polyethylene Terephthalate) product industries in and around NCR and the state of UP for configuration of physical reverse logistics networks has been shown. Further, use of optimized mixed-integer linear programming model to derive solution by Lingo solver is presented to determine numbers and locations of different key constituting facilities for the reverse logistics network, with an objective of minimizing the supply chain cost.

Keywords: Reverse Logistics, MILP

1. INTRODUCTION AND LITERATURE REVIEW

Fast growing economies like India observe a large and growing market for economic extension of product life through reuse and thereafter, a safe disposal. According to the Environmental Protection Agency, there are 20-50 million metric tons of waste electrical and electronic products generated worldwide every year, comprising more than 5 per cent of all municipal solid waste (L. L. D. C. S.-Y. and Y. V. Dat, 2012).

The economics and control over product return is far more complicated than that of the forward flow, for, reverse supply chain is generally not as much profitable as that of a forward supply chain. Contributing factors to this could be skewed ratio of capacity utilization of transport facility to the frequency of availability requirement of the product. Another aspect could be uncertainty over the quality variations of the returned products. Due to this, all the products collected cannot be remanufactured or sometimes, more advanced operations are required for making the returned product resalable (R. S. Sajan T John, 2015). This will necessitate bringing the total cost down so as not to let it consume profit margin.

Available research and literature describe about well-managing reverse logistics network to provide cost savings in procurement, recovery, disposal, inventory holding and transportation over and above helping in customer retention. Proper modelling could help reduce total reverse supply chain cost (V. J. and V. W. L. Guide). An increased thrust on environmental implications is also well documented (S. R. F. and K. H. Kara, 2007). Companies,

like Kodak, Xerox and HP which focus on remanufacturing and recovery activities, thereby achieving significant gains (H. E. G. A. E. and Ç. S. Üster, 2007).

The returned products can be classified into a number of categories. In this paper, we consider two types of product returns: One that have come to end of economic use (which can be refurbished and can be resold into secondary market); and the other, that have reached end of life (to be safely disposed-off). A framework based on the economic value analysis concept has been suggested (V. J. and V. W. L. Guide, 2001).

A mathematical programming model with heuristic solution methodology for problem solving was proposed (V. P. R. and R. E. Jayaraman, 2003). A genetic algorithm to design a reverse logistics network involving products returned was proposed by (H. K. H. and K. C. Min, 2006; and Y. a. W. S. Zhou, 2008). Zhou et al proposed a reverse distribution network design with the repairing and remanufacturing options.

Mixed-integer programming has been the most adopted modelling technique by many researchers focusing on varied components of supply chain like location-allocation of repair facilities with a TPL provider. Also, an integrated, multi echelon, multi period, multi-product mixed-integer linear programming model is suggested to optimize the distribution and inventory level for a closed loop supply chain network. These contributions take examples from different sectors like lead acid batteries, tumble driers, end-of-life vehicles, etc.

The review of the literature shows that, even though, there are lots of works in the area of reverse supply chain, only a few researchers have addressed the issue of development of a general framework for the network design. Most of the works in this area are limited to either a single type of product return (e.g. end-of-life) or a single type of recovery option (e.g. remanufacturing) (R. S. Sajan T John).

2. METHODOLOGY

In the present work, key reverse supply chain constituents contributing to sector-specific network have been examined through industrial survey for both types of product returns: end-of-life; and end-of-economic use. Further, the determination of the number and location of different facilities like collection centers, remanufacturing centers, disassembly centers, recycling centers, disposal centers is demonstrated, through real-field data of returns-flow and transportation costs of the products, components and materials between each stage in the network and also for the intra-stage quantity-flow between facilities in the reverse supply chain.

3. REVERSE LOGISTICS CONSTITUENTS

In reverse logistics, it has been established that there are three fundamental stages of flow (M. P. D. and R. Dekker, 2003; Fleischmann et al, 2004; T. U. A. a. B. A. Daim, 2013):

1) Collection, 2) sort-test, where decisions like whether to recycle/dispose-off, or remanufacture for secondary market are taken, and 3) processing (Done at recycling or remanufacturing centers)

As T. U. A. a. B. A. Daim, 2013 observes, companies need to choose how to collect recoverable products from their former users, where to inspect collected products in order to separate recoverable resources from worthless scrap, where to re-process collected products to remarket them, and further, how to distribute recovered/remanufactured products to primary/secondary customers.

For our case, the determination of the number and location of different facilities like collection centers, remanufacturing centers, disassembly centers, recycling centers, disposal centers for the reverse logistics of rubber, tyre and PET industries is demonstrated, along with the quantity of flow of products, components and materials between each stage to be established in the network and the quantity of flow of products, components and materials between each stage of the supply chain.

A reverse supply chain, existing in NCR and UP industrial zones, consisting of five market clusters, five locations for collection centers, three locations for remanufacturing centers, four locations for disassembly centers, three potential locations for recycling centers, one disposal center, two secondary markets and two primary markets are considered.

The problem involves the determination of the number and location of different facilities to be established in the network and the quantity of flow of products, components and materials between each stage of the supply chain. The objective minimizes the total cost comprising of transportation cost, processing cost, fixed facility cost and disposal cost. The network is modelled (adapted from R. S. Sajan T John, 2015) and optimized using mixed-integer linear programming formulation with minor customizations, that minimizes the total cost of the multi- stage reverse supply chain and further solved using solver Lingo.

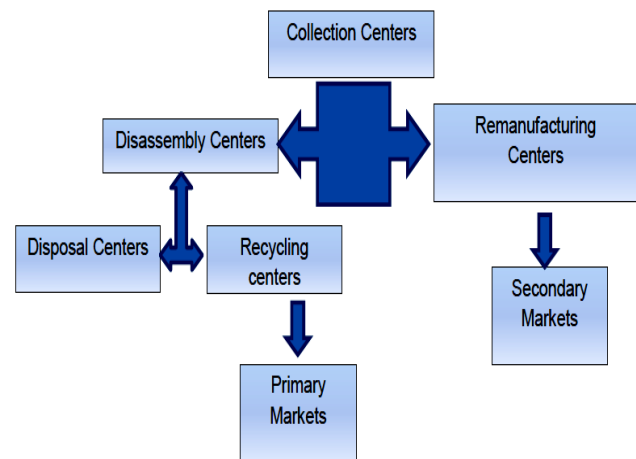


Fig. 1. Reverse logistics constituents

4. INDUSTRIAL CASE AND INPUT DATA

A real reverse supply chain consisting of five market clusters, five potential locations for collection centers, three potential locations for remanufacturing centers, four potential locations for disassembly centers, three potential locations for recycling centers, one disposal center, two secondary markets and two primary markets are considered. The coordinates of the different facilities are generated by Google maps (not shown, used only for generating distance-matrix).

In Exhibits 1 through 8, flow, cost and distance data between existing facilities is shown. The quantity of used products available for collection at market clusters are shown in Exhibit I. Exhibit II shows the distance matrix between market clusters and collection centers.

Exhibit III shows the distance matrix of collection centers with disassembly centers and remanufacturing centers. Exhibit IV shows the distance matrix between remanufacturing centers and secondary markets.

Exhibit V shows the distance matrix of disassembly centers with recycling centers and disposal center. Exhibit VI

shows distance (in KM) between recycling centers and primary markets.

5. RESULTS AND DISCUSSION

The problem is solved and optimized for a realistic situation on the pre-modelled MILP formulation. Solution tables 1 through 6 (R-1 through R-6) show the values of optimized flow and derived decision support for locational decisions for facilities to carry out constituent activities. Also shown in R-1 is the optimized cost figures.

The application of the model to the real industrial scenario provides optimum decisions for the said industrial clusters, and can be applied to cluster of similar industries. Also, through some customizations, it can further be extended for other industrial domains engaged in reverse logistics activities.

6. FUTURE WORK

The proposed model is a general one and with the proper analysis of the results obtained, it helps to analyze the long-term operation of a reverse supply chain. Further, only a single product-variants, single-period situation has been considered, and it could be further extended by considering a multi-product, multi-period situation. The uncertainty in data can also be incorporated into the study as a future research.

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EXHIBIT 1: STATISTICS OF IN-BOUND RETURNING PRODUCTS (UNITIZED QUANTITY OF PRODUCT RETURNS IN UNIT TIME FRAME)

Market clusters	Market cluster 1	Market cluster 2	Market cluster 3	Market cluster 4	Market cluster 5
Product returns	76	59	45	56	81

EXHIBIT 2: Distance (in KM) between market clusters (using Google maps)

Collection centers/ Market clusters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
1	9.5	37	63	66	41
2	59	9	43	51	28.7
3	66.8	44	7.6	49	37
4	32	31	44	29.7	17
5	62	22	37	34	6.6

EXHIBIT 3: DISTANCE (IN KM) BETWEEN MARKET CLUSTERS AND COLLECTION CENTERS (USING GOOGLE MAPS)

Collection centers/ Market clusters	1	2	3	4	5
1	6.6	49.8	71	61	47.7
2	54	9	44	42	28
3	81.5	57	9	55	52
4	26.6	31.2	66	37	21
5	62	22	37	34	6.6

EXHIBIT 4: DISTANCE (IN KM) OF COLLECTION CENTERS WITH DISASSEMBLY CENTERS AND REMANUFACTURING CENTERS

DAs/ Collection centers	1	2	3	4	5
DA 1	11	75	95	36	65
DA 2	55	21	39	16	5
DA 3	53	32	40	14	11
DA 4	77	42	16	37	10
RM 1	88	76	44	54	41
RM 2	61	75	71	38	46
RM 3	97	73	30	60	40

EXHIBIT 5: DISTANCE (IN KM) BETWEEN REMANUFACTURING CENTERS AND SECONDARY MARKETS

	Secondary Market 1	Secondary Market 2
RM 1	45	35
RM 2	14	39
RM 3	58	36

EXHIBIT 6: DISTANCE (IN KM) BETWEEN RECYCLING CENTERS AND PRIMARY MARKETS

	Primary Market 1	Primary Market 2
RC 1	66	61
RC 2	39	17
RC 3	40	20

EXHIBIT 7: CAPACITY, UNIT PROCESSING AND FIXED COSTS (IN RS. '000S) OF COLLECTION CENTERS

	Collection centers				
	1	2	3	4	5
Capacity (no. of units)	76	102	88	98	79
Fixed facility cost (in Rs. '000s)	83	98	87	105	70
Unit processing cost (in Rs. '000s)	70	71	79	76	65

EXHIBIT 8: CAPACITY, UNIT PROCESSING AND FIXED COSTS (IN RS. '000S) OF DISASSEMBLY CENTERS

Disassembly centers				
	1	2	3	4
Capacity (no. of units)	120	170	70	150
Fixed facility cost (in Rs. '000s)	200	190	150	165
Unit processing cost (in Rs. '000s)	186	195	190	182

7. RESULTS

R-1) Cost components (in Rupee value) of the objective function

Key evaluation parameters (Optimized)	Money Value (in Rs.)
Total composite cost	676486
Total cost of transportation	239560
Total fixed cost (Facility establishment)	172356
Total disposal cost	29880
Total processing cost	134690

R-2) Decision support for facility location selection decisions

Type of facility	Decision (Open at locations)
Collection centre	1, 2, 3, 4, 5
Disassembly centre	1, 2
Remanufacturing centre	2
Recycling centre	2, 3

R-3) Flow from market clusters to CCs (Optimized)

Market clusters/ Collection centres	1	2	3	4	5
Market cluster 1	77	0	0	0	0
Market cluster 2	0	67	0	0	0
Market cluster 3	0	0	85	0	19
Market cluster 4	0	0	0	52	0
Market cluster 5	0	0	19	9	51

R-4) Optimized flow from CCs to disassembly centers

	DA 1	DA 2	DA 3	DA 4
CC 1	81	0	0	0
CC 2	0	50	0	0
CC 3	0	56	0	0
CC 4	39	4	0	0
CC 5	0	49	0	0

R-5) Optimized flow from collection centers to remanufacturing centers

	Remanufacturing 1	Remanufacturing 2	Remanufacturing 3
CC 1	0	0	0
CC 2	0	22	0
CC 3	0	37	0
CC 4	0	18	0
CC 5	0	21	0

R-6) Optimized flow from remanufacturing centers to secondary markets

	Secondary Market 1	Secondary Market 2
RC 1	0	0
RC 2	0	69
RC 3	0	0

Remanufacturing Scheme Based on RUL Assessment

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Abstract: To estimate the Remaining useful life (RUL) left on a component at a particular time of operation is a vital area of research. RUL is established on maintenance and prognostics and health controlling fundamentals. RUL is typically arbitrary and indefinite as it involves various uncertainties with its calculation. The research focuses various models to estimate RUL from available sources of information using various tools and techniques which helps decision makers to find optimum policy for reuse, remanufacture and recycle.

Keywords: Prognostics, Remaining Useful Life and Remanufacturing schemes

1. INTRODUCTION

Prognostics is a skill of predicting future behavior component and identifying possible failure models resulting in computation of the remaining useful life of the component or system. It's defined as a prediction of once the failure may occur and methodology calculates the remaining useful life on an asset. (Smith. A. E. et al 2003) defined prognostics as the ability for early detection and separation of pioneer and/or initial fault condition of a factor or element. A prognostic builds on the diagnostic as a section and are defined as the capacity to predict the progression of fault condition of component failure and estimate the remaining useful life (RUL).

The remaining useful life (RUL) of component is defined whereas the length from the current time and to the end of the products useful life. RUL is applicable in theoretical and real life. Remaining useful life modeling and its assessment provide us the timely information for system for decision making, production management and condition based maintenance (Bagul Y.G. 2009). RUL is a device with vital usefulness in remanufacturing (Chen C., et al 2010), to take full benefit of the life of a device before remanufacturing, the RUL measurement is one of the best plan before any decision.

RUL prognosis is one of the key factors in condition based maintenance (CBM), and prognostics and health management. RUL prognosis techniques are tremendously desired for health management of degrading systems in order to avoid and prevent sudden breakdown and decrease the rate of hazards. RUL guess techniques can be wanted for wellbeing administration of debasing frameworks in order to avoid sudden disappointment and decrease the danger (Yang J., Jay L. 2007). RUL estimation, offers direction for successive management and investigation of inspection schedule, maintenance and replacement activities.

2. RUL EVALUATION APPROACHES

RUL estimation carries various methods to find optimum service life of component. (Bagul Y.G, et al, 2008) listed various methods to find RUL of a product is shown in fig.1. followed with the comparison table in Table 1.

2.1 Physics based methodology

Physics based methodologies are significant in circumstances where exact theoretical models may be built. These models must certainly be designed particularly for the systems may be checked and able to precisely simulate the responses and command signals. This method is helpful in various working conditions also. Having an intelligent monitoring system, they function excellently under any load conditions of undetermined, temporary and unexpected conditions of operations. These models normally include technical information thorough hypothetical models to represent the physics of the component. For hazard and proportional risk rate (Wang W., Zhang W. 2008) proposed a stochastic procedure, called gamma process, with risk rate (HR) while the mean for the expectation of remaining life. Nonlinear flow demonstrates approach anticipated the remaining life of a musical instrument with a nonlinear procedure.

2.2 Data driven methodology

Data driven strategies, does not required any comprehensive data of the component. They are based on condition and observing/ monitoring data. Methodology became helpful when noisy data required to be changed into logical data to evaluate the RUL, (Yang J., Jay L. 2007).

RUL estimation is dependent upon extent quantity and qualities of the data. Data driven methodology are developed by collecting input and output data by various methods. Data driven prognostic technique is dependent upon statistical systems while most that begin in the

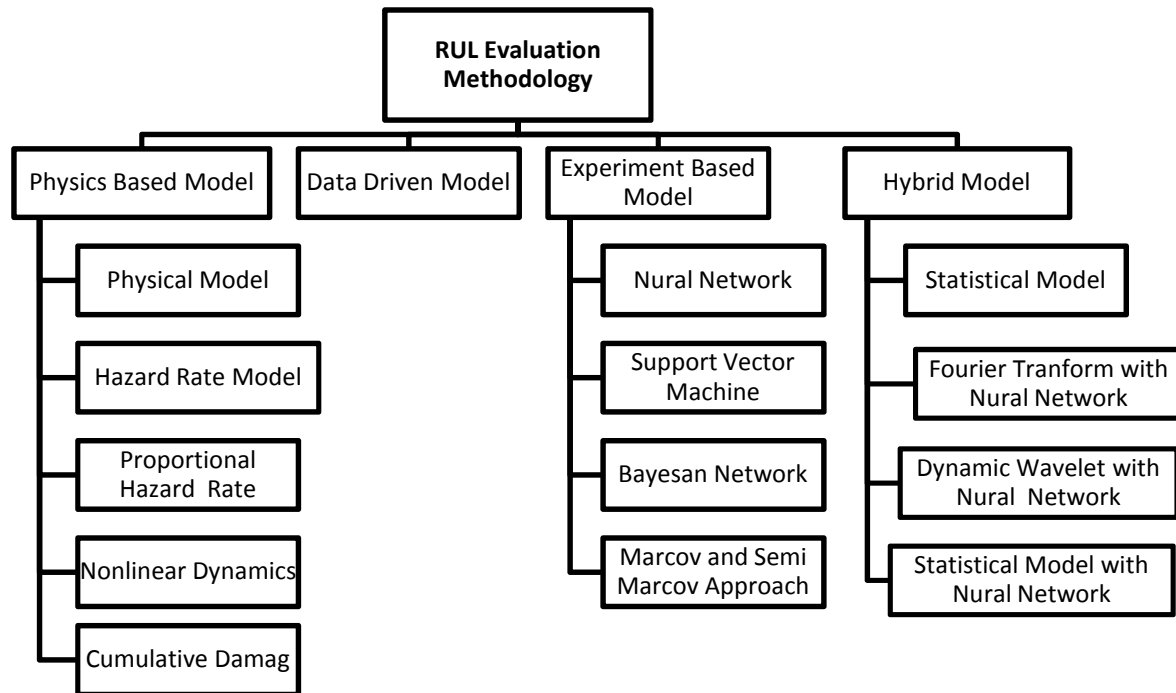


Fig. 1. Approaches for the RUL evaluation

theoretical data. Such approaches envelop traditional numerical calculations, like linear regression, algorithms, data mining, neural networks, decision trees etc.(Peng et al 2010).

2.3 Experimental based methodology

Experiments are defined as the best method to enhance the knowledge of component's life has been a vital approach in research and industry since automation is found its way to manufacturing practices. (Keller et al. 1982 and Groeret al. 2000).

Theoretical modeling became second selection of researchers because experimental research in industry is a must but while the behavior of machines is understood by analyzing the experiments it becomes most prominent step among all. Thus, experiments are often are the first and most important step for a researcher. (Chen et al. 2010) used experimental data from the key gearbox of a UH-60 helicopter, as this method is also used to validate other methods.

2.4 Hybrid methodology

In prognostic processes, parameters are miscellaneous it difficult to be predicted with by only one estimation method and results obtained with a single method isn't completely reliable. Now researchers adopting to make use of multiple method in conjunction produce for more accurate results

(Bagul et al. 2009) resulting methodology is termed a cross methodology.

TABLE 1.Comparison of Prediction Methodology

Physics based Models	Data driven Models	Experimental Models
It is highly accurate model if physics of the system remains reliable across the system.	Models transform high-dimensional noisydata in to prognosticdecisions and also measures input/output.	Manipulations in data set can be controlled. Possibilities to add trend analysis based on theexperimental data.
Model is based on various assumptions and empirical considerationsof physics parameters.	Model does not require assumptions or empirical estimations of physics parameters.	Models are almost always needed to verify other theoretical models.
Computation of this model is expensive.	Easily to calculated and envisage further states. But prediction horizon is shorter.	Experimental models are often costly.
It can be built with less input dataset compared to data driven method.	Gives poor result with high dimensional data. Accuracy of data set increases accuracy of measurement	Theoretical and experimental models generates more accurate output.

3. UNCERTAINTY IN RUL MEASUREMENT

There are some sourced elements of uncertainty which affect the estimation of future behavior and consequently the rest of the useful life prediction. Those sourced elements of uncertainty, is practically impossible to exactly so estimate hence the rest of the useful life prediction becomes more uncertain. It may even more challenge to identify and quantify the different sources of uncertainty that affect prognostics. Such categorized the different sources of uncertainty into different sets in order facilitate uncertainty quantification and management. Prognostics

based decision-making model it is important to analyze how the many sourced elements of uncertainty affect the rest of the useful life prediction, in order to accurately estimate the uncertainty in the RUL prediction and inform the decision maker regarding such uncertainty (Bagul Y.G. 2009). Tasks need to be performed for accurate estimation of the uncertainty in the RUL prediction and update the decision maker regarding such uncertainty. Modeling errors, , sensor noise and, state, future loading, model parameters, operating and environmental conditions, measurement error etc. are common source of uncertainty (Keller A., Perera U., Kamath A. 1982).

TABLE 2: Stages to Reduce Uncertainty

Uncertainty Illustration and Interpretation (Bukapatnam S.T.S 1997)	In this stage level of uncertainty is measured lots of practical applications are guided by the possibility of modeling and simulation frameworks from pair of theories like: classical set theory, fuzzy set theory, fuzzy measure theory, probability theory rough set theory, etc. The strategy for uncertainty representation that vary in the level of datasets and detailing.
Uncertainty Quantification	The following stage is to handles identifying and characterizing the sources of uncertainty that may affect prognostics and RUL estimation. Aim of this is to manage all these uncertainties individually and enumerate those using probabilistic or statistical methods.
Uncertainty Propagation	This stage is highly relevant to prognostics, because most of the previously quantified uncertainties and uses these details to predict the near future states and the associated uncertainty; and for remaining useful life and the associated uncertainty
Uncertainty Management	Uncertainty administration is in reference different activities which assist in managing uncertainty in condition-based maintenance during real-time operation.

4. DECISION CRITERIA BASED ON RUL RESULTS

Remanufacturing of a part can be a choice as a most valuable task as using the components whole life base on reliability. Deciding the very best time to pull the part from service for remanufacturing as a function of total cost optimization and reliability function various calculations are required. (Usynin A.V, 2007), decision for remanufacture, re-use and recycle is proposed based on data, forecasts, information of the performance and reliability value.

Decision criteria is founded on, reliability of component at time as $R(t)$, measuring/ predicting reliability of the exact same component $R(t+l.\Delta t)$ at time $t+l.\Delta t$. Predefined threshold reliability R^* is defined for every product. Measuring current reliability $R(t)$ and reliability after time is $R(t+l.\Delta t)$ we can take decision for remanufacturing.

You can find three different solutions for the remanufacturing scheme (Xugang et al 2007), as shown in the next:

1. Reuse: Reuse the product without remanufacturing if the present time reliability $R(t)$ is larger than the predefined threshold reliability R^* , and the near future reliability at $t+l.\Delta t$ time is $R(t+l.\Delta t)$ is also greater compared to the threshold reliability R^* , as in Fig.2(a). $R(t) > R^*$ and $R(t+l.\Delta t) > R^*$.

2. Remanufacturing: Product could be used effectively up to the worth of reliability is higher than threshold reliability. Product could be remanufacture if present time reliability $R(t)$ is superior to the predefined threshold reliability R^* , and the prospect reliability at $t+l.\Delta t$ time is $R(t+l.\Delta t)$ is less than the threshold reliability R^* , as in Fig. 2(b). $R(t) > R^*$ and $R(t+l.\Delta t) < R^*$.

3. Recycle: The possibility of the products failure is relatively frequent and to improve operational reliability of the merchandise, remanufacturing is preferred, but after that recycle phase come in to account. Product can be recycle if the present time reliability $R(t)$ is fewer than the predefined threshold reliability R^* , and the future reliability during the time $t+l.\Delta t$ is $R(t+l.\Delta t)$ is also less compared to the predefined threshold reliability R^* , as in Fig.2(c). $R(t) < R^*$ and $R(t+l.\Delta t) < R^*$. Reliability of product is decreased below the threshold margin and struggling to perform the specified operations, so it's advisable to recycles.

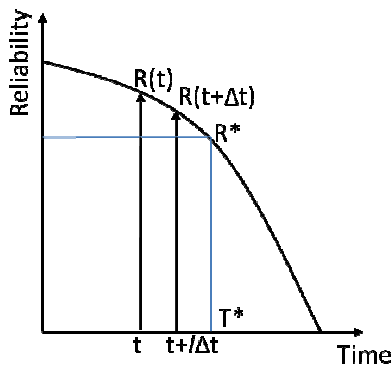


Fig.2(A) Reuse as an conclusion

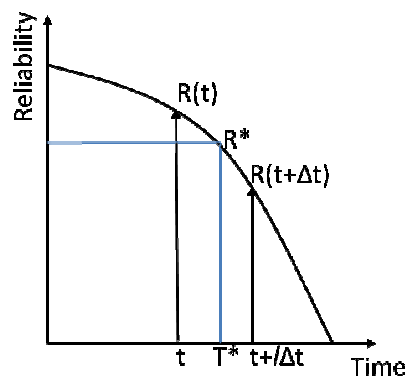


Fig.2(B) Remanufacturing as an conclusion

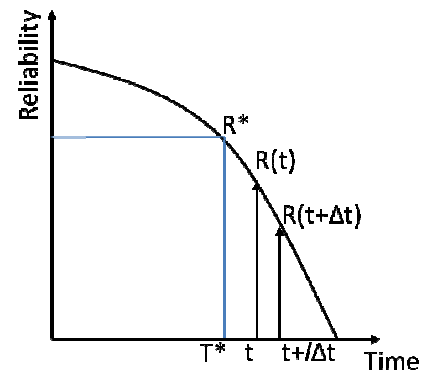


Fig.2(c) Recycle as an conclusion

5. CONCLUSION

Accuracy in prediction of maintenance strategy has received a lot of attention as engineering focus on reducing high maintenance costs, timely delivery and operation downtime and safety working environment became prime for any organization. Maintenance and prognostics is essential; as they estimates and improves the RUL of equipment which prevents inopportune maintenance expenses. RUL can be measure using various methods explain in the paper. Based on reliability value decision maker can make decision for remanufacturing. This data-driven method is followed by steps of data gathering, training, and exercise for the model construction is necessary. The theory connects the remanufacturing scheme with the performance reliability and RUL serves as best tool for remanufacturing decision. The prediction of remaining useful life in engineering systems is afflicted with several sourced aspects of uncertainty, and it is important to suitably interpret this uncertainty to be able to assist significant decision.

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Supply Chain Performance Measurement: A Literature Review

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Abstract: *In today's competitive business environment, supply chain performance is one of the most critical issues in various industries. It is stated that supply chain performance measurement is fundamental to efficient supply chain management. Over the past two decades, several frameworks and systems have been developed to meet this need. This study reviews the literature in the field of supply chain performance measurement and gathers an overview of those systems, approaches, techniques and criteria. Findings disclose that performance measurement in supply chain contexts is still a fruitful area of research. The study also provides an overview of the performance measures employed in supply chain systems.*

Keywords: *Supply Chain, Sustainable supply chain, Critical success factors*

1. INTRODUCTION

A supply chain (SC) is a set of processes that are linked together the activities such as the procurement, logistics, production and distribution of products to customers (Zanjirani, Farahani, and Davarzani 2009). Supply chain management (SCM) has strategic relevance because increased competitive pressures have pushed many firms to turn their supply chain into competitive weapons to enhance performance (Fine, 1998). Critical success factors (CSFs) of SCM represent a wide variety of strategies devoted to improving operational efficiency and competitiveness of SME. To effectively compete in the global market, SMEs must have effective SCM performance measurement system.

In view of this, objectives of this paper is to study the literature related to supply chain performance measurement. We will discuss the background for the research, review the selected literature on supply chain performance measurements, and finally, summarize the findings and conclusions.

The rest of this paper is organized as follows. Section 2 briefly reviews the literature on supply chain performance measurement. Finally, conclusions are presented in Section 3.

2. LITERATURE REVIEW OF SUPPLY CHAIN PERFORMANCE MEASUREMENT

In this section, the literature is used in relating the general perspective within which measurement of supply chain performance is undertaken. The works of various authors are used in establishing the need for supply chain performance measurement are considered in this paper.

Luque et al. (2015) focuses on the interrelationships among the different dimensions of supply chain integration. Specifically, it examines the relationship between employee commitment and supply chain integration dimensions to explain several performance measures, such as flexibility, delivery, quality, inventory and customer satisfaction. The findings suggest that the relationship between employee commitment and operational performance is fully mediated by supply chain integration. Employee commitment contributes to improving internal integration, and internal integration affects performance both directly and indirectly. Moreover, obtaining internal integration helps to achieve supplier and customer integration. Author gives various dimensions of supply chain performance measurements. Author also claimed that lack of qualitative research in this area (Luque et al., 2015).

Top management commitment, long term vision, focus on core strengths, devoted resources for supply chain, and development of effective SCM strategy emerged as the most pertinent CSFs. To measure improvement in performance, different measures related to customer service and satisfaction, innovation and growth, financial performance, and internal business should be included (Kumar, 2015). It is possible to improve supply chain performance by implementing Lean SCM practices. That is particularly important in a country that has high interest rates and needs to compete in a global market (Tortorella et al., 2017).

Payman et al. (2016) proposed an integrative multidimensional framework for a comprehensive evaluation of SSC performance. The key contribution of research presented in this literature is that the proposed stochastic framework is capable of accommodating any number of performance characteristics associated with

SSCM. The framework is not restricted to the three traditional areas of the triple bottom line, namely economic, environmental, and social issues. This is important given the wide range of challenges and opportunities present in different supply chains. It is recognized that a key challenge in applying the framework is data availability and quality. The proposed framework provides a genuine foundation for evaluating the performance of SSC while the cumulative impact of all the involved factors in all the entailed periods is taken into account. Lastly, by considering as many SSCM characteristics as may be involved, the proposed framework can be employed as a practical tool by decision-makers who aim to effectively highlight and/or manage the required reference points, when identifying the available opportunities and challenges for improving their SSC performances. The developed framework may also provide opportunities for making performance comparisons between various SSCs, provided that the entailed required data are collected, allocated, and reported in the same way across all the SSCs under comparison.

There are number of factors which urge company executives to seek new types of metrics to evaluate the performance of supply chains (Lambert and Pohlen, 2001):

- need to go beyond the limits of the company's business,
- lack of metrics covering the entire system of cooperating links,
- need to determine the range of cooperation between cooperators,
- complexity of processes,
- need for information exchange in order to achieve objectives,
- need to broaden the perception of supply chains,
- distribution of costs and benefits among the partners,
- need to diversify supply chains,
- encouragement to develop cooperation in order to improve processes.

Other authors also notice this problem and stress that there are no methods for measuring the performance of supply chains as a whole, the metrics and indicators applied do not reflect the complexity of processes and the applicable criteria are not closely linked to the supply chain strategy (Lapide, 2010). Despite efforts to integrate a supply chain, the measurement aspect gets out of this coordination. Supply chain measurement is not a single coherent system, but actually a model of measuring the performance of individual companies as if they worked independently. Each link in a supply chain has its own system. What is worse, often the same aspect of measurement is interpreted differently by individual companies. Therefore, it is

absolutely necessary to use the same terminology and apply common metrics, which are understandable for all cooperating links and which really measure the performance of the entire system adequately.

Yinan et al. (2017), developed a comprehensive model that facilitates an understanding of relationships among operations strategies, supply chain strategies, supply chain integration, and firm performance. It is a start to understand the role of operations strategies in supply chain design. Structural equation modelling is adopted to test the relationships based on data collected from 604 Chinese manufacturers. The results showed that a lean supply chain is appropriate for firms placing higher priorities on cost, quality and delivery strategies, while an agile supply chain is appropriate for firms competing on the flexibility strategy. Furthermore, both lean and agile SCSs require higher levels of SCI in terms of internal and external integration, but lean SCSs have a significantly higher impact on external integration than agile SCSs. The study refreshes the links between order winner/qualifier and supply chain strategies. Clear-cut differences exist concerning the role of operations strategy in supply chain management, indicating that appropriate supply chain design is very important for firms to achieve their operations objectives. This study contributes to a better understanding of the match between operations strategies and supply chain strategies, and offer a practical insights on investments in the development of supply chain integration.

M. Agung Wibowo et al (2015), developed SCOR model to measure performance of supply chain at road construction project. Research in industry and organization, about performance measurement of supply chain explains the Supply Chain Operations References (SCOR) with dimensions of reliability, responsiveness, flexibility, costs, and assets (D. Irfan, 2008). The previous study about the measuring performance of supply chain in house building indicates that the framework is needed to identify the balance of supply chain performance. Supply chain performance measurement on the road project has not been much discussed today. As it is known that the road project is one of very high construction project roles. The road becomes a liaison between local lands. In addition, road project becomes the backbone of the economy of a region wheel movements with the mobilization of people and goods from one area to another. Road project requires a strong supply chain, especially road with high function such as toll roads. Therefore, supply chain performance measurement on road projects is necessary to determine the ability of contractor. Performance measurement using the Supply Chain Operations References (SCOR) will analyze how the supply chain management of contractor is. SCOR will analyze how the reliability, responsiveness, flexibility, cost, and assets of the contractor. Based on the analysis, it can be seen how the performance and readiness of the

contractor in supply chain management. The more ready supply chain of contractors in road project, the higher the possibility of subject to success.

Madjid Tavana et al. (2016) proposed model that can be used both under the constant returns to scale and the variable returns to scale assumptions and can be easily implemented for comprehensive analysis of multi-level supply chains. We present a numerical example to demonstrate applicability of the proposed model and exhibit the efficacy and effectiveness of the proposed algorithms and procedures. In particular, the numerical results demonstrate that the entire supply chain is “comprehensively” efficient only if efficient supplier–manufacturer and manufacturer–distributor relationships are established.

Dominique Estampe et al. (2013) prepared framework which analyzes various models used to assess supply chains by highlighting their specific characteristics and applicability in different contexts. It also offers an analytical grid breaking these models down into seven layers. This grid will help managers evolve towards a model that is more suitable for their needs.

3. CONCLUSION

Thus in this article fundamentals regarding the supply chain management are discussed in the introduction session. Also, importance of performance measurement of supply chain management are elaborated. Section 2 describes about the quantitative literature available on performance measurement of the supply chain. In this number of authors have proposed frameworks or quantitative models for evaluating or measuring the performance of supply chain. Also some cases like road construction business and its performance evaluation are explained.

Thus after reviewing the literature it is concluded that performance measurement of supply chain is more fruitful area of research and lot of work can be carried out on the prescribed area.

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Cloud Computing: Supply Chain as a Service

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Abstract: The severe competition prevailing in today's marketplace makes it integral for firms to maximize their operational efficiency and responsiveness. Optimization of the supply chain can aid organizations in attaining the dynamism to achieve the same. Cloud computing is an emerging technology which has the potential to enable this optimization through flexible outsourcing software that provide platform, software and infrastructure services for the whole supply chain network via Internet. Despite the myriad benefits, the limitations and risks while incorporating the same must be taken into account. This paper focuses on the application of cloud computing in improving the supply chain collaboration and visibility needs. The pros and cons of adopting this technology in dynamic supply chains is further discussed.

Keywords: Cloud Computing, Supply Chain Management, SaaS, PaaS, IaaS

1. INTRODUCTION

The supply chains of today are highly fragmented and dynamic with silos of information that make it almost impossible to share information with all the trading partners. Therefore, to have a competitive edge in the market, businesses must be able to make quick decisions to re-route shipments, track products, communicate and collaborate with the entire global trade network to meet customer demand.

Cloud computing is one such service which makes it easy to share massive amounts of information across a complex supply chain. It is a technology that helps in the delivery of on-demand computing applications and services over the internet on a pay-for-use basis. Cloud computing consists of three different service models namely Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS), each one of them serving different requirements of cloud users.

Infrastructure-as-a-Service (IaaS): IaaS model is a platform through which businesses can avail equipment in the form of hardware, servers and storage space on a pay-as-you-go basis.

Platform-as-a-Service (PaaS): In this model, cloud providers host a computing environment including an operating system, data base and programming language execution environment, where users develop or deploy applications.

Software-as-a-Service (SaaS): SaaS model is a software delivery model providing on-demand access to applications through a web browser or a program interface.

The application of cloud computing concept in the context of supply chain management is an innovative practice that

generates a new field of study with numerous advantages such as capital investment savings, simplified operations, flexibility, real-time visibility, as well as sustainability in the supply chain. These advantages offered by cloud computing help organizations to maintain alignment between ever-evolving supply chain initiatives and IT, thus enhancing firm agility which refers to an organization's ability to sense, adapt, respond and perform well in the face of rapidly changing environments. However, risks and limitations such as security of private information should be taken into consideration before applying cloud computing in modern supply chain networks [Graham et al., 2013].

The following sections of the paper are structured as follows. Section 2 briefly reviews the literature on adoption of cloud computing in supply chain management. Section 3 explains the concept of supply chain as a service. The entire supply chain management of an organization is divided into four cycles and the benefit of using cloud technology in each of these respective four cycles is mentioned. To give a more holistic view, the positive and negative impact of using cloud computing in global supply chains is mentioned. Finally, the conclusion is presented in section 6.

2. LITERATURE REVIEW

Digital Supply Chain integration is becoming increasingly dynamic. Access to customer demand needs to be shared effectively, and product and service deliveries must be tracked to provide visibility in the supply chain. Business process integration is based on standards and reference architectures, which should offer end-to-end integration of product data. Cloud integration can be expected to offer a cost effective business model for interoperable digital supply chains [Korpela et al., 2017]

This 2016 supply chain trend will continue as best-in-class organizations leverage business networks to create a digital community of partners executing coordinated processes in a more organized and informed and create value for all parties involved in it[Kayikci, 2018]

Cloud storage has revolutionized many industries and logistics is no different. By implementing self-updating and hosted computer systems, cloud storage offers many benefits to warehousing include cutting down on maintenance, infrastructure and labour costs that come from the installation and upgrading of warehouse management systems. Another benefit is that cloud storage systems are often self-updating. This means that, instead of replacing talented tech-savvy members of the team once they leave, a system can be implemented that is cost effective and easy to use by all members of staff [Tirkkonen, 2017]

New cloud computing technologies are enabling breakthrough innovations in supply chain management (SCM) applications delivered via software as a service (SaaS) models. Cloud computing is now recognized as a real game-changer, providing a route through which supply chain executives can rapidly and efficiently access innovative solutions—delivered through a SaaS model—and deploy them at scale. Driven by growing realization of the benefits these solutions provide, the SaaS for SCM market is predicted to grow by 24 percent in 2014, and reach a 19 percent compound annual growth rate to become a US\$4.4 billion opportunity by 2018.SaaS-based approaches work well when collaborative processes are involved [Kowalkiewicz, 2017]

Cloud computing adoption in supply chains is heavily dependent on the legacy ERP systems in place, as they provide the system of record corporate-wide. 56% of survey respondents have standardized on SAP ERP systems followed by Oracle (including PeopleSoft & JD Edwards) 16% and the remainder being multiple ERP systems.7% of respondents don't have an ERP system today.46% of respondents report that greater supply chain collaboration leads to problems being solved twice as fast. Cloud computing platforms are becoming more pervasive in large-scale supply chains as enterprises look to gain agility and speed in resolving complex problems through more effective collaboration.[Cegielski et al., 2012]

3. CLOUD COMPUTING: SUPPLY CHAIN AS A SERVICE

Flexibility being an important need of today's dynamic supply chains, it has seen an integration of cloud computing technology to combat it. Therefore, Supply Chain as a Service is an upcoming field of study.

Supply Chain as a Service will cater to the interaction of two or more stages/ parties of the supply chain for the flow of information and funds, by using the services provided by the cloud.

It's network of multichannel and interconnected businesses in the cloud involved in the end-to-end supply chain activities. Hence catering to the two way flow of the information, services and funds across the cloud from the supplier to the end customer.

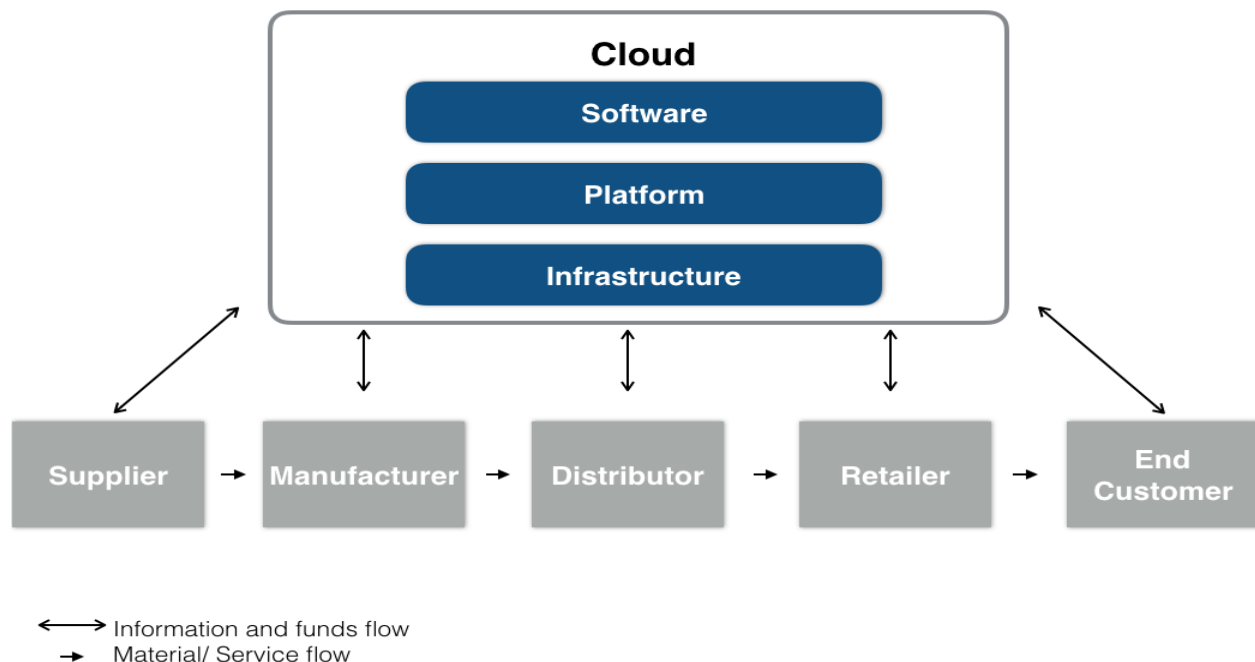


Fig. 1. Cloud integrated end to end supply chain processes

This will enhance the working of companies in several ways. For startups, it will reduce the infrastructural investments which would in-turn help them to develop in shorter period of time. It will also increase the pace at which new services and products are introduced in the market. For the existing companies, this infrastructural benefit and the upcoming competition from them will make them re-invent their supply chain to constantly improve it. Thereby on a whole, making the supply chain more scalable and dynamic.

3.1 CYCLE VIEW OF SUPPLY CHAIN PROCESSES: A CLOUD BASED APPROACH

The processes that comprises of the supply chain are divided into a series of cycles each performed at the interface between two successive stages of the supply chain. Fig. 2 describes each cycle and the stages it connects. The efficiency and flexibility of each cycle of the supply chain can be increased by developing a cloud based infrastructure. The scope and capacity of each cycle on the cloud is discussed below.

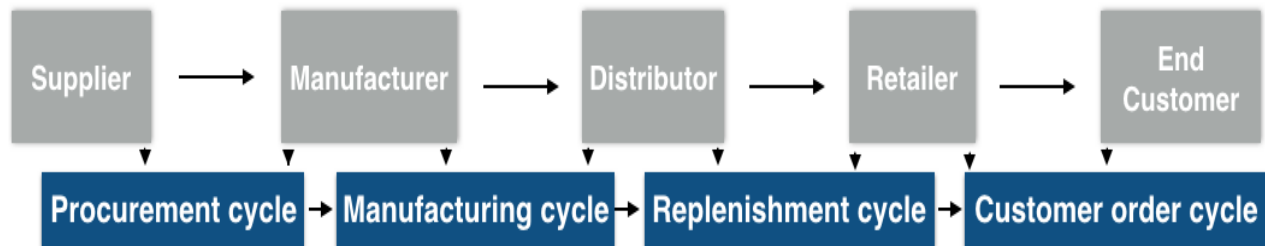


Fig. 2. Cloud integrated end to end supply chain processes

1. **Procurement Cycle:** Through cloud computing ‘the total cost of ownership’ is reduced. This is because of the collaborative and accessible nature of the cloud based tools that optimizes the speed, cost and flexibility. It significantly reduces the burden on companies catering to thousands of suppliers on a regular basis. By creating a database of the suppliers on the cloud, contract management for each stage of the supply chain can be improved. Thereby leading to improved visibility all across the supply chain.
2. **Manufacturing Cycle:** The cloud technology can make the product design phase modular. This is by allowing individual setting while maximizing the performance of service. Even while manufacturing, it has high utilization in cases of highly fluctuating and flexible demand by planning and forecasting the manufacturing run.
3. **Replenishment Cycle:** The designed cloud based platforms helps companies to improve their service levels by coordinating the supply chain among partners. It can capture SKU wise spend data, performance based analytics, planning on the replenishment quantity and forecasting demand. These software can be used for- planning & allocating, assortment & space and replenishment. These collaborative planning and forecasting tools helps in reducing the Bullwhip effect across the supply chain. Apart from this, lead time can be controlled by Strong Service Level Agreements (SLAs) with the vendors. The inventory is optimized by having an optimum buffer for unpredictable demand.
4. **Customer order Cycle:** Effective management of customer data can be done by the use of the cloud technology. Enormous companies have various ways of providing customer service and managing orders. For the ease of this, cloud technology will help in the speedy aggregation and analysis of the customer data for their regular sales & promotion opportunities.

Also, one of the major areas where cloud computing can reduce the complexity of a supply chain is *Logistics*. Cloud computing applications for inventory management, transportation route planning, fleet management, global trade compliance, network strategy, warehousing and transportation are emerging. The main advantage of moving to the cloud is the ease of tracking of products/ services across the supply chain moving in both direction, either forward or backward (reverse supply chains). The recent development of the RFID (Radio- Frequency Identification) helps in tracking the product location and transmitting it back to the cloud. Hence, increasing the traceability in the supply chain.

In logistics, cloud technology is essential for 3PL companies for managing warehouse activities and planning of the optimum transportation route for different customers in one single system.

3.2 POSITIVE AND NEGATIVE IMPACT OF ADAPTING CLOUD COMPUTING IN SUPPLY CHAIN NETWORKS

POSITIVE IMPACT

Cost efficiency: It can be effectively used by firms in supply chain management with financial benefits. Here the

cloud services are provided by third party providers which reduce the investment, maintenance and upgrading costs. The capital costs are considered as a part of operational costs resulting in a net positive cash flow. The only costs that the firm pays is the activation cost and the usage fee as per requirements.

Simplification: A single platform is used to access all parts of the supply chain removing any compatibility and connection problems and enables all partners to share supply chain information in a single system. New members need just a set of password and surname to become a part of the collaborative committee. A single system reduces the response time of one partner to another's decisions. Hence, cloud services provide the basis for information control through a single centralized storage system ensuring the smooth flow of information.

Flexibility: A wide variety of applications can be hosted in a single cloud based platform. Access to the cloud can be made location independent by using common devices. This provides the supply chain the agility to introduce new products and services into the market.

Visibility: Timely connectivity among various supply chain participants is made possible through visibility. Visibility is an issue with 3PL services providers due to the absence of real-time inventory, shipment and logistics tracking. Cloud based systems eliminate this problem and provide for real-time tracking. These systems can act as virtual warehouses that enable strategic order fulfillment decisions and dynamic inventory re-routing decisions based on the actual product location.

Scalability: Cloud computing systems allow supply chain stakeholders to control their supply chain capacity according to demand fluctuations. In the absence of cloud, the stakeholders must hold the necessary database in order to meet customer demand and must hold an additional database just to meet excess demand for a short period of time. Cloud computing enables scaling and descaling according to demand forecasts.

Sustainability: There remains doubts on whether cloud computing really encourages sustainability. However, if many companies use the same cloud infrastructure, economies of scale can be leveraged to minimize the unit energy consumption.

NEGATIVE IMPACTS

Data Security and Privacy: Access to the cloud data should be limited to only authorized and trustworthy supply chain partners. Confidentiality can not be always ensured as these systems are vulnerable to hacking. Data acquisition by rival firms would pose an imminent threat to the whole supply chain.

Outdated Mindset: Sharing of data and information with the public represents a drastic change in the traditional culture business values. Many firms believe that keeping information about their supply chains or production processes provides them with a competitive advantage. Disclosure of such data to cloud systems instills the fear that this competitive advantage could be lost. Adoption of cloud systems implies a radical change in the business models incorporated in the whole supply chain network. Supply chain partners have to adapt their skill set to move from using common on-premises infrastructure to effectively use cloud systems. Such a transition is a time taking one.

Availability: Many firms are concerned with the crashing or disruption of cloud services. This is because these delays will directly affect a firm's supply chain operations and financial in turn, their financial welfare. Another concern is access to the cloud from different geographical locations with varying internet speeds.

Lack of Customization: Cloud services are often one size fits all. They do not fit specific supply chain operations and are hence avoided in the manufacturing industry where complex procedures are performed. A lack of customization could lead to a slow market response or even a loss of competitive advantage.

4. CONCLUSION

As mentioned above, there are both advantages and disadvantages of using the cloud technology for supply chain management. However as the potential benefits outweigh the limitations, it is recommended for firms to incorporate the cloud computing models effectively in order to collaborate and communicate among the supply chain stakeholders through the integration of supply chain activities. Therefore, companies that want to constantly improve and re-invent their supply chains should adopt cloud computing technology with consequent positive aspects.

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Interpretive Structural Modeling for Analysis of GSCM Enablers

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Abstract: The rapid economic and industrial growth of highly populated developing/emerging nations is posing serious environmental and social problems not only in their own countries but also to the world. A growing number of organizations have begun or are willing to work towards implementing Green Manufacturing (GM) in these nations. But the adoption of GM is a challenge for the organizations in these nations as motivating factors (drivers) are not facilitated. The objective of this paper is to identify the enablers to implement green supply Chain and to understand their mutual relationship. Green supply chain management (GSCM) enablers are identified using available GSCM literature and on consultations with experts from industry and academician. Interpretive structural model (ISM) was developed to identify the contextual relationship among these enablers. This study will be helpful for both practitioners as well as academicians. The practitioners need to concentrate on identified GSCMEs more cautiously during GSCM implementation in their organizations and the top management could formulate strategy for implementing these enablers obtained through ISM and MICMAC analysis.

Keywords: Green Supply chain management (GSCM), GSCM enablers, Interpretive structural modeling, MICMAC.

1. INTRODUCTION

With the economic performance, the environmental performance has become increasingly important for organizations facing competitive, regulatory, and community pressures. With increased pressures for environmental sustainability, it is expected that enterprises will need to implement strategies to reduce the environmental impacts of their products and services (Zhu et al., 2005). To achieve the environmental performance, the organizations are trying to implement an environmental management system (EMS) over a last two decade. EMS has the primary purpose of preventing negative effects on the environment. This is achieved by developing environmental practices. The adoption of cleaner production processes, greener products, and measures of environmental performance also contribute to the successful implementation of an EMS. For the successes of EMS, the organizations should consistently strive for the reduction and elimination of all waste streams associated with the design, manufacturing, use and/or disposal of products and materials, maintaining air quality, etc. Till date, most of the organizations have implemented ISO 14000 system. ISO 14000 is the most widely accepted EMS certification accepted globally.

Over a last decade, the organizations and regulatory authority realized that, mere controlling the environment related issues insight the organization is not sufficient, and all the parties of SC should contribute to the same. The involvement of all the parties for environmental concern

can be treated as GSCM. For successful GSCM, a huge cooperation effort and the involvement of multiple actors are required, such as, from government to citizen, from organization to customers, and from organization to its suppliers. Therefore, selecting partners (suppliers, distributors, etc.) are an important step in creating a truly green and efficient SC.

The implementation of GSCM requires support of various factors like, employee environmental training, employee environmental empowerment, and employee environmental teamwork, training to suppliers and society, government support, cooperation with supplier and customer for eco-design, and cleaner production etc.

GSCM implementation requires identification of green supply chain management enablers (GSCMEs). Many researchers have discussed various GSCMEs which helps organization to achieve better organizational performance. But identifications of GSCMEs is not adequate, successful GSCM implementation requires identification of interrelationship between various GSCMEs and find out the GSCMEs having strong driving power (GSCMEs which helps to achieve other GSCMEs) and dependence power (GSCMEs which are largely dependent on other GSCMEs). The interrelationship between various GSCMEs and driving and dependence power can be obtained through interpretive structural modeling (ISM) model and Matriced' Impacts Croise's Multiplication Applique'e a' un Classement (MICMAC) analysis. In this paper, 14 GSCMEs have been

identified on the basis of literature review and the opinions of experts from academia and industry experts.

2. LITERATURE REVIEW

Governmental legislations, environmental concerns, and customer awareness, more and more industries are giving attention to green practices (Thomas and Bijulal 2011; Wang and Gupta 2011). Top management Commitment is necessary for supporting GSCM ideas, practices, and cooperation across organizational functions (Zhu et al. 2007), and success of any strategic program needs to be derived from top Management (Yu and Hui 2008). Top management has a significant ability to support actual formation and implementation of green initiatives across the organization. Top management may provide continuous support for GSCM in the strategic and action plans for successful implementation (Ravi and Shankar 2005; Mudgal et al. 2009). Trowbridge (2001) distinguished between internal and external drivers for the implementation of GSCM at a chip manufacturer. Internal drivers include the willingness to improve risk management due to potential interruptions in the supply chain, and the collaboration with suppliers to find alternative materials and equipment that minimize environmental impacts. External drivers include customers, investors and non-governmental organizations. The growth in this green supply chain literature extends back to the early 1990s with the advent of corporate environmental management, environmentally conscious manufacturing strategy, and supply chain management literature (Zhu and Sarkis, 2006). Previous research has identified that organizations can face a variety of barriers and enablers to sustainable SCM (Seuring and Muller, 2008), and that these can be either internal or external to the organization (Hervani et al., 2005; Walker et al., 2008).

Walker et al. (2008) reviewed the literature and identified the factors that drive or hinder organizations to implement green supply chain management initiatives; these includes internal drivers such as organizational factors, and external drivers such as regulation, customers, competitors, society and suppliers. Based on interviews conducted at seven different private and public sector organizations, they further identified the internal barriers such as cost and lack of legitimacy, as well as external barriers such as regulation, poor supplier commitment and industry specific barriers.

Rao and Holt (2005) observed that greening different phases of the supply chain leads to an integrated green supply chain, which in turn leads to competitiveness and better economical and operational performance. Wee and Quazi (2005) identified seven critical factors in their research into environmental management: top management commitment; total involvement of employees; training; green products/process design; supplier management;

measurement; and information management. Green purchasing has been an important issue since early 90's (Hwa, 2001). Green purchasing consists of involvement in activities which include the reduction, reuse and recycling of materials in the process of purchasing (Ninlawan et al., 2010). Reverse logistics is the process of retrieving the product from the end consumer for the purposes of capturing value or proper disposal (Ninlawan et al., 2010). Bowen et al. (2001) analyzed the relationship between supply management capabilities and green supply practices and identified internal drivers for implementing green supply policies (strategic purchasing and supply, corporate environmental pro-activity, and supply management capabilities.)

Interpretive Structural Modeling (ISM) can be used for identifying and summarizing relationships among specific variables, which define a problem or an issue (Warfield, 1974; Sage, 1977). It provides some means by which order can be imposed on the complexity of such variables (Jharkharia and Shankar, 2004; Ravi and Shankar, 2005; Faisal et al., 2006). GSCM also encompasses the collaboration-based approach. This approach includes training and education programs given to suppliers, environmental managerial information sharing, and collaborative research with suppliers (e.g., Vachon and Klassen, 2006; Min and Galle, 2001; Bowen et al., 2001; Lippman, 1999). Shang et al. (2010), explored key green supply chain management (GSCM) capability, six green supply chain management dimensions were identified: green manufacturing and packaging, environmental participation, green marketing, green stock, green suppliers, and green eco-design. Diabat and Govindan (2011), identified the drivers influencing the implementation of GSCM using an Interpretive Structural Modeling (ISM) methodology and extracted 11 drivers collected through past literature: Certification of suppliers' environmental management system; environmental collaboration with suppliers; collaboration between product designers and suppliers to reduce and eliminate product environmental impacts; government regulation and legislation; green design; ISO 14001 certification; integrating quality environmental management into planning and operation process; reducing energy consumption; reusing and recycling materials and packaging, environmental collaboration with customers; and reverse logistics. The common drivers are identified through the existing literature and with the combined assistance of company experts. The Common drivers are provided as competitors, stakeholders, company image, financial benefit, environmental conservation, customers and compliance with regulations.

Using available GSCM literature and on consultations with experts panel including 4 academicians and 5 experts from

industry working in the field of GSC, following 14 GSCME are indentified.

GSCME Code	Green Supply Chain Enablers
GSCME1	Public Pressure
GSCME2	Current and future Legislation
GSCME3	Supply chain pressure
GSCME4	Top management commitment
GSCME5	Organizational Resources
GSCME6	Customer Demand
GSCME7	Technology
GSCME8	Green manufacturing
GSCME9	Green Design
GSCME10	Reverse Logistics
GSCME11	Competitiveness
GSCME12	Cost Saving
GSCME13	Economical Benefit and competitiveness
GSCME14	Incentives

3. ISM METHODOLOGY AND MODEL DEVELOPMENT

ISM was first proposed by J. Warfield in 1973 to analyze the complex socioeconomic systems. ISM enables

individuals or groups to develop a map of the complex relationships between many elements involved in a complex situation. Its basic idea is to use experts' practical experience and knowledge to decompose a complicated system into several sub-systems (elements) and construct a multilevel structural model. ISM is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem.

The methodology of ISM modeling adopted from Ref. Gorane and Kant (2013).The various steps involved in the ISM methodology are as follows:

3.1. Structural Self-Interaction Matrix (SSIM)

A group of experts, from industries and the academics was consulted in identifying the nature of contextual relationships between the QEEs. For analyzing QEE in developing SSIM, the following four symbols have been used to denote the direction of the relationship between the QEEs (i and j):

V - GSCME i lead to achieve GSCME j;

A - GSCME j lead to achieve GSCME i;

X - GSCME i and j lead to achieve each other; and

O - GSCME i and j are unrelated.

TABLE 3: Structural self-interaction matrix (SSIM)

GSCME Code	14	13	12	11	10	9	8	7	6	5	4	3	2
GSCME1	V	V	V	V	V	V	V	V	X	V	V	X	X
GSCME2	V	V	V	V	V	V	V	V	X	V	V	X	
GSCME3	V	V	V	V	V	V	V	V	X	V	V		
GSCME4	V	V	V	V	V	V	V	V	A	V			
GSCME5	V	V	V	V	V	V	V	V	A				
GSCME6	V	V	V	V	V	V	V	V					
GSCME7	V	V	V	V	V	V	V						
GSCME8	V	V	V	A	X	X							
GSCME9	X	V	V	A	X								
GSCME10	V	V	V	A									
GSCME11	V	V	V										
GSCME12	X	V											
GSCME13	A												

3.2 Initial and Final Reachability Matrix

The SSIM has been converted into a binary matrix, called the initial reachability matrix (see Table 2) by substituting V, A, X and O by 1 and 0. By incorporating the transitivity, the final reachability matrix obtained

TABLE 4: Initial Rechability Matrix

GSCME Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GSCME1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
GSCME2	1	1	1	1	0	1	1	1	1	1	1	1	1	1
GSCME3	1	1	1	1	0	1	1	1	1	1	1	1	1	1
GSCME4	0	0	0	1	1	0	1	1	1	1	1	1	1	1
GSCME5	0	0	0	0	1	0	1	1	1	1	1	1	1	1
GSCME6	1	1	0	1	0	1	1	1	1	1	1	1	1	1
GSCME7	0	0	0	0	0	0	1	1	1	1	1	1	1	1
GSCME8	0	0	0	0	0	0	0	1	1	1	0	1	1	1
GSCME9	0	0	0	0	0	0	0	1	1	1	0	1	1	1
GSCME10	0	0	0	0	0	0	0	1	1	1	0	1	1	1
GSCME11	0	0	0	0	0	0	1	1	1	1	1	1	1	1
GSCME12	0	0	0	0	0	0	0	0	0	0	0	1	1	1
GSCME13	0	0	0	0	0	0	0	0	0	0	0	0	1	0
GSCME14	0	0	0	0	0	0	0	0	0	0	0	1	1	1

TABLE 5: Final Rechability Matrix

GSCME Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GSCME1	1	1	1	1	1*	1	1	1	1	1	1	1	1	1
GSCME2	1	1	1	1	1*	1	1	1	1	1	1	1	1	1
GSCME3	1	1	1	1	1*	1	1	1	1	1	1	1	1	1
GSCME4	0	0	0	1	1	0	1	1	1	1	1	1	1	1
GSCME5	0	0	0	0	1	0	1	1	1	1	1	1	1	1
GSCME6	1	1	0	1	1*	1	1	1	1	1	1	1	1	1
GSCME7	0	0	0	0	0	0	1	1	1	1	1	1	1	1
GSCME8	0	0	0	0	0	0	0	1	1	1	0	1	1	1
GSCME9	0	0	0	0	0	0	0	1	1	1	0	1	1	1
GSCME10	0	0	0	0	0	0	0	1	1	1	0	1	1	1
GSCME11	0	0	0	0	0	0	1	1	1	1	1	1	1	1
GSCME12	0	0	0	0	0	0	0	0	0	0	0	1	1	1
GSCME13	0	0	0	0	0	0	0	0	0	0	0	0	1	0
GSCME14	0	0	0	0	0	0	0	0	0	0	0	1	1	1

Note: * represents transitivity

3.3. Level Partitions

From the final reachability matrix, the reachability set and antecedent set for each GSCMEs are found. The reachability set includes GSCME itself and others which it may help to achieve, similarly the antecedent set consists of GSCME itself and the other GSCMEs which help in achieving it. Then, the intersection of these sets is derived for all GSCME. The GSCMEs for which the reachability and intersection sets are same is the top-level GSCMEs in the ISM hierarchy. The top-level GSCMEs in the hierarchy would not help achieve any other GSCMEs above its own level. Once the top-level GSCMEs are identified (Table 6), it is separated out from the other GSCMEs.

TABLE 6: Partitioning of reachability matrix: first iteration

GSCME Code	Reachability Set	Antecedent set	Intersection set	Level
GSCME1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	
GSCME2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	
GSCME3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	
GSCME4	4, 5, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 6	4	
GSCME5	5, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6	5	
GSCME6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	
GSCME7	7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 11	7	
GSCME8	8, 9, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 9, 10	
GSCME9	8, 9, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 9, 10	
GSCME10	8, 9, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 9, 10	
GSCME11	7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 11	7, 11	
GSCME12	12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	12, 14	
GSCME13	13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	13	I
GSCME14	12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	12, 14	

TABLE 7: Level of SCMEs

GSCME Code	Reachability Set	Antecedent set	Intersection set	Level
GSCME1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	VII
GSCME2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	VII
GSCME3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	VII
GSCME4	4, 5, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 6	4	VI
GSCME5	5, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6	5	V
GSCME6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 6	1, 2, 3, 6	VII
GSCME7	7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 11	7	IV
GSCME8	8, 9, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 9, 10	III
GSCME9	8, 9, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 9, 10	III
GSCME10	8, 9, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 9, 10	III
GSCME11	7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 11	7, 11	IV
GSCME12	12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	12, 14	II
GSCME13	13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	13	I
GSCME14	12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	12, 14	II

3.4 Building the ISM mode

Structural model is generated using final reachability matrix (Table 5), If there is a relationship between the GSCMEs i and j, this is shown by an arrow which points from i to j. This graph is called a directed graph, or digraph. After removing the transitivity the digraph is finally converted into the ISM-based model (Figure 1).

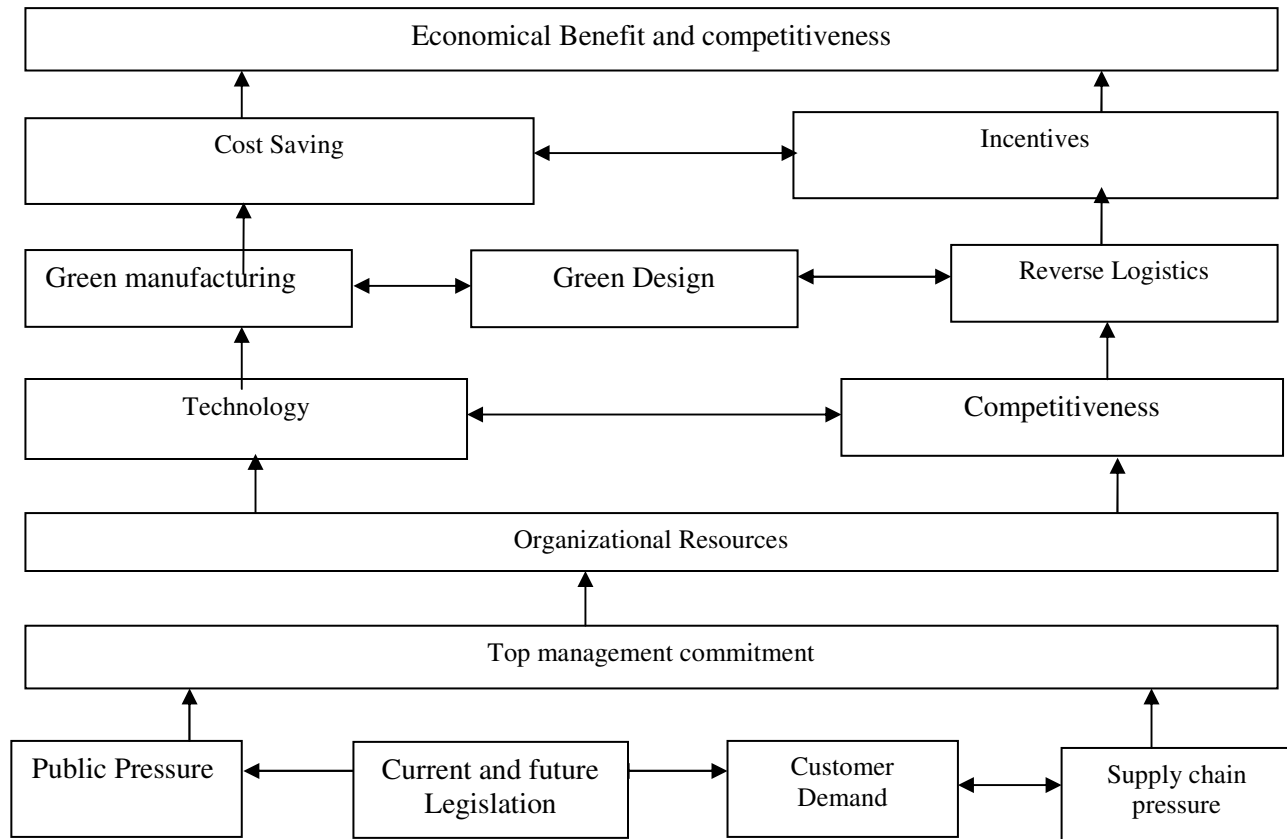


Fig. 1. ISM Model Formulation for GSCM Enablers

4. FINDINGS AND DISCUSSIONS

It has been found that GSCM implementation has become an essential prerequisite to staying in the global competitive market. Though the organizations are benefitted by GSCM implementation, but implementing GSCM in an organization is challenging and difficult or costly to implement. A range of GSCMEs can help it to achieve successful GSCM implementation.

The main objective of this research work is to identify and find out the interdependencies among all selected GSCMEs and further to analyse the driving and dependencies of GSCMEs for successful GSCM implementation in the organization. To achieve these objectives, ISM-based model and MICMAC analysis have been deployed in order to understand the interactions among different GSCMEs completely so that management may lay stress more on enablers which are more effective for GSCM implementation. This will help to improve organizational performance and productivity in the organization and thus

will help in improving customer satisfaction. In this paper, 14 GSCMEs have been identified on the basis of literature review and the opinions of experts from academia and industry experts. The interrelations between the various GSCMEs were obtained from academicians and group of industry experts.

ISM is used by various researchers for modelling the GSCM variables for improving the GSC performance. ISM technique has been applied to many areas of GSCM like ISM in vendor selection, Reverse logistics, IT implementation, GSC performance measurement and so on. However, a major contribution of this research lies in the development of linkages among various GSCMEs for entire GSC through ISM and MICMAC analysis. In this research, the ISM MICMAC approach is used as; ISM provides only binary relationship between identified variables; while the MICMAC approach provides sensitive analysis related to driving and dependent behaviour of GSCMEs.

The other objective of this paper was to analyze the driving and dependence power of the GSCMEs that influence the GSCM implementation in an organization through MICMAC analysis. In MICMAC analysis the GSCMEs are classified into four clusters (Figure 2). The first cluster consists of the autonomous GSCMEs that have weak driver power and weak dependence. These GSCMEs are relatively disconnected from the system, with which they have only few links, which may be strong. Second cluster consists of the dependent GSCMEs that have weak driving power but strong dependence. Third cluster has the linkage GSCMEs that have strong driving power and also strong dependence. These GSCMEs are unstable and any action on these GSCMEs will have an effect on others and also a feedback on themselves. Fourth cluster includes the independent GSCMEs having strong driving power but weak dependence. The analysis of MICMAC is as follows.

4.1 Autonomous GSCMEs

The driving-dependence power diagram shows that there are no autonomous GSCMEs in the process of GSCM implementation. Autonomous SCMEs are weak drivers and also weak dependent. The autonomous GSCMEs are relatively disconnected from the system. Hence, they do not have much influence on the system. Therefore, among the 14 selected GSCMEs, all the SCMEs have much influence in the GSCM implementation.

4.2 Dependent GSCMEs

GSCME1, 2, 3, 4, 5, 6, 7, 11 are weak drivers but are strongly dependent on others (Figure 2). They are seen at the top of the ISM hierarchy (Figure 1), therefore considered as important GSCMEs. Their strong dependence indicates that they require all the other GSCME to minimize the effect of these GSCMEs during GSCM implementation. The management should therefore accord high priority in tackling these GSCMEs.

4.3 Linkages SCMEs

There is no GSME in this linkage category that has a strong driving power and also a strong dependence (Figure 2). Any change occurring to these GSCMEs will have an effect on others and also a feedback on themselves. Hence, these GSCMEs are unstable in nature which may affect the successful GSCM implementation in the organizations.

4.4 Independent GSCMEs:

The driving power and dependence diagram (Figure 2) indicates that independent GSCME8, 9, 10, 12, 13, 14 having less driving Power and more dependence power. Thus, management needs to address these GSCMEs more cautiously and may be treated as the root cause of all the GSCMEs. It has been observed that these GSCMEs help to achieve GSCMEs which appear at the top of ISM hierarchy.

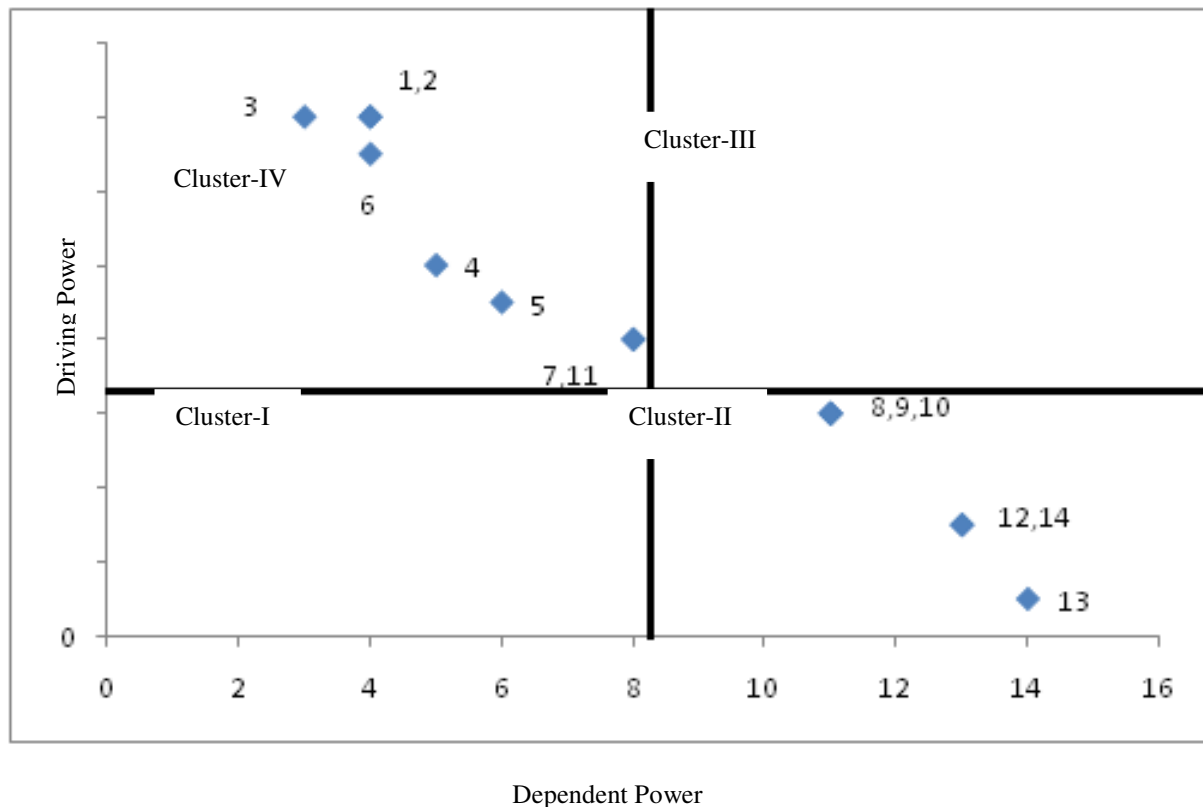


Fig. 2. MICMAC Analysis

5. CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

GSCM implementation is tough task due to the complexity of GSCM practices, customer awareness and increase in cost of product and regulation. Decision makers must be aware of the relative importance of the various drivers and the techniques for implementing them. This paper has identified 14 key GSCMEs by reviewing a number of research articles. It is moreover evident that no single GSCMEs would be self-determining for GSCM implementation in an organization, therefore, it becomes more important to identify the relationship of GSCMEs with each other. ISM methodology is used to develop relationship among various GSCMEs for each dimension of GSCM implementation. MICMAC analysis is carried out to identify the driving and dependence power of GSCMEs using ISM result.

In this research work, integrated model of GSCMEs is developed using ISM and MICMAC approach, which may be helpful to GSC managers to employ this model in order to identify and classify the important GSCMEs for their needs and to reveal the direct and indirect effects of each GSCME on the GSCM implementation. The finding of paper provides important guidelines for both practitioners as well as the academicians. ISM model identifies the hierarchy of actions to be taken by practitioners in order to maximize the effect of these GSCMEs in order to implement GSCM successfully. The MICMAC analysis indicates the category of the GSCMEs which needs attention by practitioners according to their dependence power and driving power. Practitioners should concentrate on those GSCMEs which have higher driving power because these GSCMEs should be emphasized for effective and successful GSCM implementation. These higher driving GSCMEs are root cause for the other GSCMEs which have higher dependence. Once these higher driving power GSCMEs are identified, the top management could formulate strategies for enhancing their effects during GSCM implementation.

ISM model development and MICMAC are obtained through the judgments of academicians and few industry experts. Any biasing by the person who is judging the GSCMEs might influence the final result. Hypothesis testing, structural equation modeling (SEM) and case studies may be carried out to validate the model.

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E-commerce: Past, Present and Future - An Indian Perspective

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Abstract: Internet and its associated information technologies significantly transformed the way we live our life. It touches every aspect of our life and one of the aspects is our purchasing habit. This report mainly focuses on retail E-commerce or B2C (Business to Consumer). Since inception earlier in 1995, E-commerce is enjoying the era of explosive growth. This paper deals with the introduction of E-commerce, its definitions, the difference between E-commerce and E-business, E-commerce organizations and its classification based on types of transactions and involved parties and benefits of E-commerce to organization and consumer. Further, it gives an overview of evolution of E-commerce at global as well as India level. E-commerce current scenario with major statistics, leading E-commerce models discussed in chapter three. Apart from this, the paper discussed key drives of E-commerce in India. It gives an idea about key challenges faced by E-commerce industry in India and highlights of future trends of E-commerce in India. Finally, Conclusion and recommendations are discussed.

Keywords: E-commerce, Past, Present, Future, opportunities, Challenges, India

1. INTRODUCTION

The Internet has changed the way live our life. Every minute of our life is augmented by its use for sharing our view, virtual engagement on social networking site, digital entertainment, marketing and even buying and selling. If organizations want to take advantage of latest Internet technologies, then they should take the strategic initiative. One of the most significant areas where the company can focus is E-commerce. Electronic commerce is a revolutionary era which is growing and continuously changing the way business has been managed. Moreover, it becomes the base for a new form of business around the world. Further, Industry value chain is redefined by E-commerce and blow the bugle for the new complex competitive environment. Looking into these scenarios, organizations are going to face immense pressures and challenges due to economic reforms towards new digital/virtual markets. Organizations need to keep up with this groundbreaking changes which have the capacity to transform the whole economic infrastructure. If organization wants to endure then they have to develop awareness and understanding about the constantly progressing and growing complex environment of E-commerce to compete globally. Along with this tremendous growth in Smartphone, tablet, lightweight laptop prompted a new E-commerce platform called Mobile commerce (M-commerce) and Social commerce (S-commerce).

What is E-commerce

When we think of E-commerce the first thing comes in our mind is Amazon, Flipkart – an online shopping websites for retail goods. In simple since E-commerce means to buying

and selling on the internet. The definition of E-commerce in the modern times implies that a transaction is termed as electronic commerce if it typically uses the World Wide Web at least at any point in the transaction's lifecycle[2]. According to UK government "E-commerce is the exchange of information across electronic networks, at any stage in the supply chain, whether within an organization, between businesses, between businesses and consumers or between the public and private sector, whether paid or unpaid" (Cabinet Office, 1999). Another definition is given by AMA Electronic commerce or E-commerce refers to a wide range of online business activities for products and services[3]. E-commerce refers to various online commercial activities focusing on commodity exchanges by electronic means, Internet in particular, by companies, factories, enterprises, industrial undertakings and consumers[4]. The government of India defines E-commerce as buying and selling of goods and services including digital product over the digital and electronic network (DIPP 2016). These definitions signify that electronic commerce is not solely restricted to the actual buying and selling of products, but also includes pre-sale and post-sale activities across the supply chain. Since E-commerce is a brand new science, it is not at all surprising that there are various definitions about it.

2. EVOLUTION OF E-COMMERCE – INDIA

E-commerce has its existence in India since last 15 years. It was only a topic for discussion in India until in 1999 Reiff.com added India's first online shopping platform to its portal followed by the launch of Bazee.com in 2000 and the journey of E-commerce (Table I) begins.

TABLE I: Evolution of E-commerce Timeline (India)

Timeline	Historical Event
1999	Rediff.com added online shopping to its portal
2000	Bazee.com was launched which had the good response from Indian customer. In 2004 it was acquired by eBay
2002	The Indian government launched IRCTC – an Online Passenger Reservation System
2003	Airlines in India followed the Indian railways and introduce online air ticket booking system
2005	Makemytrip.com, Started its operations in India by providing online flight ticket to travel and then after extended in holiday packages and hotel booking
2006	Yatra.com launched to provide online flight ticket booking services
2007	Bookmyshow.com entered and become the largest entertainment ticketing website. At the same time, B2C based E-commerce started in India by the introduction of Flipkart.com with its discount model
2009	Myntra.com was launched, it selling the retail fashion and lifestyle products to Indian customers. At the same time, Mydala.com was started. It was India's first group buying site like Groupon
2010	Its time for snapdeal.com in India. Started and daily deals platform which becomes an E-commerce company via marketplace model
2011	BuildaBazaar.ooo created e platform for small Indian seller by providing the self-service portal where a user can create e-store, upload product catalog, customize the site and sell their product. At the same time Groupon enter in India by acquiring SpSaSta.com and first re-branded it as “Crazeal” then “Groupon India, now ‘nearbuy.com’”
2012	An Indian fashion and lifestyle portal Jabong.com was launched
2013	Amazone.in was launched in Indian started with electronic and extended with fashion, beauty, home essential and health care categories
2014	Flipkart.com acquired Myntra.com in an estimated Rs. 2000 cr.

Source: <http://blog.softwaresuggest.com/ecommerce-in-india/> (26/11/2016)

3. E-COMMERCE IN INDIA

India's GDP is expected to increase 7.6% in 2017 and it is expected to increase to 8.1% in 2018[12]. This will lead to more domestic as well as foreign investment in growing

sectors of India. The retail sector is growing at 11% CAGR and estimated to US\$600 billion in 2016 to US\$1 trillion in 2020. Even though total E-commerce in India accounts only 2% of total spending on retail, E-commerce is becoming the key factor to create the new market which previously unreachable. There are significant infrastructural changes happening in Indian economy with respect to rapid adoption of advanced technology that supports the growth of E-commerce. Technological adoption in India is high especially in Smartphone segment due to affordable and easy to use features. India became the second largest country after China for Smartphone penetration with 220 million users in 2016. Moreover, during the same time, internet penetration is also significantly rising with the number of internet users at 354 Million as of September 2015. In addition to this, there is a shift in mobile usage from voice to data. Mobile internet spend has risen from 54% to 64% from 2014 to 2015. This is due to an availability of high-speed 3G & 4G internet connectivity at affordable prices which has led to an increase in transactions done via mobile[13]. Further, India's rank for ease of doing business went up by 4, from 134 to 130 in just one year[14]. India rank 39th among 138 countries on global competitiveness index has jumped by 16 ranks from 55th rank in 2015 which indeed a significant improvement for India[15] and that is because of the improved regulatory framework that creating a conducive business-friendly environment. These factors are going to have the positive impact on foreign investment in India.

This above positive indicator leads foreign and domestic investments in India mainly in E-commerce industry which is expected to be a value of US\$101.9 billion in 2020. Further due to other infrastructural development in terms of Digital advertisements, Logistics, Digital payment, Finance support, Technology and training to MSMEs for E-commerce platform enable faster growth rate of E-commerce in India.

TABLE II: E-commerce in India and its future predictions

India - E-commerce (Only B2C)	2015	2020*
Total E-commerce size	US\$16 billion	US\$101.9 billion
Online shopper as a % of internet user	11%	36%
Number of online shopper in India	39 million	220 million
Average spend per online shopper in India	US\$247	US\$464

Source: CII report: *e-Commerce in India - a Game Changer for the Economy 2016*[13]

TABLE III: Indicative list of current leading E-Commerce models in India

E-commerce Models	Leading companies
B2C E-commerce marketplace	Snapdeal.com, Amazon.com, Flipkart.com
B2C E-commerce inventory led	BigBasket.com, FirstCry.com, Zovi.com
B2C E-commerce Aggregator	Uber.com, olacabs.com
C2C E-commerce	Cloudacar.com, quickr.com, olx.in
B2B E-commerce	Mjunction services limited (metal junction, coaljunction, buyjunction, etc.), cloud Buy.com, tolexo.com, industrybuying.com, power 2sme.com, Amazonbusiness.com
Omni-channel retailer	Shoppers Stop Ltd., Infiniti Retail Limited Croma, Raymond Limited
<i>Source: CII report: e-Commerce in India -a Game Changer for the Economy 2016[13]</i>	

TABLE IV: Indicative list of emerging Vertical Specific E-Commerce companies in India

E-commerce Models	Leading companies
Online Travel	Makemytrip.com, yatra.com, cleatrip.com, goibibo.com
Online Real Estate	Magicbricks.com, 99acres.com, commonfloor.com, Housing.com
Online Fashion	Jabong.com, Myntra.com, Zovi.com, yepme.com, limeroad.com
Online Furniture	Fabfurnish.com, Pepperfry.com, urbanladder.com
Online Education	Purple Squirrel Eduventures, Plancess.com
Online Food and grocery	Zomato.com, Foodpanda.in, TinyOwl.com, BigBasket.com, Grofers.com

TABLE V: Indicative list of emerging Online Aggregator Models in India

E-commerce Models	Leading companies
Online Health	Portea.com, Healthkart.com,
Online Laundry	Wassupondemand.com, DoorMint.in, LaundryWala.co.in
Online Entertainment	Netflix.com, ErosNow.com, Hooq.com
Online Truck Booking	TruckSuvridha.com, TruckMandi.in, The Karrier.com, Fortigo.com

Source: CII report: e-Commerce in India -a Game Changer for the Economy 2016[15]

Based on Gross Merchandise Value most of the global E-commerce companies shows the low profit in spite of having the presence for 5 to 20 years. This scenario continues in India i.e. Indian E-commerce companies showing growth in terms of GMV but overall incurring losses. On the other hand trend is different in the B2B segment in India. B2B market Valued at \$300 billion in 2014 and expected to reach at \$700 billion by 2020 in India. The profit margin, volume of purchase, importance of quality rather than price and lack of heavy discount are the few reasons attributed for B2B segment profitability.

The Government has allowed 100% FDI through automatic route in B2B E-commerce and 100% FDI under automatic route is permitted in Marketplace model of E-commerce. FDI is not permitted in inventory led based model of E-commerce. FDI in B2C is permitted in following conditions. 1) Manufacture is permitted to sell its product manufactured in India through E-commerce retail. 2) A single brand retail trading entity operating through brick and mortar store is permitted to undertake retail trading through E-commerce. 3) An Indian manufacturer is permitted to sell its own single-brand products through E-commerce retail. Indian manufacture would be the investee company, which is the owner of the Indian brand and which manufactures in India, in terms of value, at least 70% of its product in-house, and source, at most 30% from Indian manufacturers[16].

B2B, B2C, C2C, and Omni-channel retailer models currently exist and emerging E-commerce models (Table III & IV) in India. Basically, B2C further can be classified as Marketplace Model; Investor led Model and Aggregator Model. Vertical specific E-commerce (Table V) companies are also emerging in Traveling, Fashion, Real Estate, Furniture, Educational and Food-Grocery segments. E-commerce Aggregators (Table 6) digitizing several offline services and creating a convenient ecosystem and online platform in the area of Health, Laundry, Entertainment and Truck booking. Online Aggregators besides providing the comparison of price and features across service providers are also connecting buyers directly with sellers, thus reducing costs to consumers by obviating middle-men.

4. KEY CHALLENGES OF E-COMMERCE INDUSTRY IN INDIA

The e-commerce industry is enjoying above mentioned drivers that boosting the growth and acceptance of E-commerce in India. However, there are many challenges encountered by the E-commerce companies. These challenges (Table VI) are mainly related to Infrastructural support, Customer acquisition, satisfaction and loyalty, Government policies and legal framework and scaling and profitability of organization etc.

TABLE VI: List of Key Challenges faced by B2C E-commerce industry in India

Key Challenges	
Cash on Delivery (CoD) as a mode of payment	Customer's preference for CoD increases chances of return and results in locking up of working capital for both the platform and the sellers.
Network and bandwidth dependency	Access to E-commerce platforms, through desktops, mobiles, and other devices are dependent on the network bandwidth.
Merchant's lack of online experience	Small merchants are uncomfortable and unfamiliar with technology and need to be trained on the use of E-commerce technology.
Digital payment transaction failure	Due to lack of high-speed bandwidth and inefficiencies in payment gateway technology, the E-commerce industry is facing high transactions failure rates leading to customers dissonance
Dependence on Telecom Operators for rural penetration Navigating Procurement Process of companies	E-commerce companies, who want to expand into tier II & III cities, are dependent on the Telecom Operators to roll out 3G/4G into such areas for connectivity.
Logistic and Reverse logistics	Poor supply chain infrastructure in tier I and II cities are creating the problem for last mile delivery. Currently, reverse logistics is highly inefficient, which results in high inventory and increased costs. Apart from this what about customer delivery experience is still the question mark.
Lack of customer loyalty	Currently, customers are mainly attracted through discounts and have very little brand loyalty. Customers easily and frequently switch among platforms based on

	best discount offered by them.
High cost of customer acquisition	Intense competition and heavy discounting have resulted from customer acquisition and retention costly for E-commerce companies.
Scaling and profitability of organizations	B2C E-commerce companies have raised and infused capital from investors to scale operations. However, from a profitability perspective, the losses have grown faster than sales. Majority of the companies rely on discounting for customer acquisition leading to an absence of long-term sustainable business models.
Tax framework	Due to the absence of a uniform tax structure, States have adopted different tax frameworks and Inter-State goods movement is a challenge. It not only increases operational and compliance costs but also delays timely delivery of goods.
Security and Counterfeit products and services	There is an increasing incidence of cyber thefts and payment thefts in the industry today. Additionally, the supply of fake, counterfeit products by the merchants on the platform is on a rise.

Source: CII report: *e-Commerce in India -a Game Changer for the Economy 2016* & PWC report 2016[13]

5. FUTURE OF E-COMMERCE IN INDIA

5.1 E-commerce Predictions

Future of E-commerce is bright and fascinating (Table VII) globally as well as in Asia. Same case with the India, where total B2C sales are US\$24.61 Billion in 2016 and projected to reach US\$68.47 Billion by 2019 which will be still only 4.8% of total retail sales. India is the 3rd largest country in terms of having the number of digital buyers that is 112.7 Million in 2016 which likely to reach 239.7 Million by 2019 which will be still only 24.3% of total population in 2019.

TABLE VII: B2C E-commerce industry current size (2016) & growth prediction (2019)

B2C E-commerce industry size – World, Asia, and India (US\$)		
Worldwide Total B2C sales	\$2.050 Trillion (2016)	\$3.578 trillion (2019)
Worldwide total B2C % of total retail sales	8.6%	12.8%
Asia-Pacific Total B2C sales	\$1, 152.21 Billion	\$2, 336.27 Billion

Asia-Pacific total B2C % of total retail sales	12.4%	20.4%
India total B2C sales	\$24.61 Billion	\$68.47 Billion
India total B2C % of total retail sales	2.6%	4.8%
India B2C sales growth rate	75.8%	23.9%
Worldwide Digital buyers	1.61 Billion	2.07 Billion
Asia-Pacific Digital buyers (share worldwide)	812.2 Million (50.4%)	1139.6 Million (55.1%)
Asia-Pacific Digital Buyer Penetration (% of internet users)	54.8%	62.0%
Asia-Pacific Digital Buyer Penetration (% of population)	25.4%	34.7%
India Digital buyers (3rd rank)	112.7 Million	239.7 Million
India Digital Buyer Penetration (% of internet users)	43.8%	64.4%
India Digital Buyer Penetration (% of population)	12.0%	24.3%
Source: eMarketer 2016 report on worldwide retail e-commerce sales.[9]		

6. CONCLUSION AND RECOMMENDATIONS

Indian E-commerce industry is growth stage and showing tremendous potential. E-commerce begins its journey in 1999 and today, in 2016 it becomes the fastest growing industry (Growth rate 75.8% - 2016 eMarketer) of India. The Higher rate of Internet and Smartphone penetration, availability of 3G and 4G connectivity and improvement of doing business rank of India further promotes investment in E-commerce industry in India. Presently, in India Inventory led and Marketplace are two model of B2C E-commerce exist. Apart from this B2B, C2C and Omnichannel retailers are also growing. Vertical specific E-commerce model and Online Aggregators model of E-commerce is also emerging. The growth that has been seen by the E-commerce industry is accountable to significant changes happening in Indian economy which support the growth of E-commerce in India. These changes include Governmental policy development and initiative like Digital India, Start-up India, Innovation Fund, Skill India, Make in India, Goods, and Service Tax etc., Internet and smart penetration, New Digital Payment Solutions, logistic support are acting as a key driver for the growth of E-commerce industry.

The Indian government is working on infrastructural and legal issues whereas for profitability and scaling of the organization largely depend on how E-commerce company managing their customers. This is true same for the high customer acquisition cost and high preference for CoDs. Using services of new startups in the logistic sector, acquiring logistic companies and backward integration by E-commerce can be the solution for last mile delivery problem in India. Further, combined efforts of government and industry can bring the boost to the adoption of new payment methods which might migrate payment from cash to card payment and from card to digital and mobile payment. Wallet space is emerging to support online payment by creating the secure option for payment to gain

the trust of customers. Effective acquisition and retention of the customer by finding faster and innovative solutions to the challenges faced by E-commerce industry will be the key to success. E-commerce Company needs to understand customer online shopping adoption and issues related to it and enhance customer purchase experience to generate the higher rate of loyalty and satisfaction for emerging market in Tier II & III cities of India. Taking futuristic approach E-commerce companies now need to focus more on service aspect by shifting from discount model to business model and should think in the direction for creating and sustaining strong brand of itself.

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Supply Chain Management Practices in Industry

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Abstract: Sustainable Supply Chain Management (SSCM) has attracted considerable interest among industries. The aim of paper is to present a critical review of the literature, to discuss for the use of SSCM through a framework, and suggest further research directions. It is observed that environmental and social performance have a positive relationship with economic performance. The present study has several practical implications which would enable managers to adopt sustainable practices in their supply chain. Sustainable supply chain management (SSCM) is now identified as a primary factor in promoting industrial sustainability. SSCM effectively manage the material, information and capital flows associated with the procurement, production and distribution of products or services to fulfil short term and long term profitability.

Keywords: Sustainable Supply Chain Management (SSCM), Green supply chain management (GSCM), Industry

1. INTRODUCTION

Increased competition at the supply chain level, rapid changes in customer demand patterns and pressures from governments and other stakeholder groups has encouraged most companies to increase its attention on adoption of sustainability practices. Supply chain interferences may benefit a company's unaffected competitors. However, market conditions may affect companies within an industry in a similar way. Many industry competitors share suppliers, transporters, and manufacturers, indicating that interferences at one company may have negative consequences for the competitors.

Ashby et al. (2012) and Halldorsson et al. (2009) have discussed that the word 'sustainability' is over stretched and it may be that the level of attention is raised by unnecessary inflation surrounding sustainability in supply chains. Beske and Seuring (2014) have discussed that a sustainable supply chain differs from a conventional supply chain. There is also strong evidence suggesting that sustainability in supply chain networks has helped organizations to achieve better performance (e.g. Tsoufas and Pappis, 2006; Yusuf et al. 2013; Plambeck et al. 2013). Few empirical studies are available on sustainability, most of them primarily focus on environmental practices (Govindan et al., 2015; Chen et al., 2015; de Giovannia & deVinzi, 2012). On the other hand, there are significant number of empirical studies that concentrates only on the social dimension of sustainability (Bai et al., 2015; Hutchins & Sutherland, 2008; Baske et al., 2008). Further, there are studies that investigate only the economic aspect of sustainability (Avami, 2013; Bottani & Rizzi, 2008; Turkay et al., 2004; Rao & Holt, 2005; Gunasekaran et al., 2001). However, in order to have a whole and broad understanding of the mechanisms involved in a sustainable supply chain, studies should be carried out that consider all dimensions of sustainability (Jakhar, 2015;

Silvestre, 2015). Implementation of sustainable practices in supply chains is fraught with several challenges. These challenges lead to negative impacts particularly during initiation stage of sustainability practices (Faisal 2010; Zaabi, Dhaheri, and Diabat 2013). automobile supply chain has a significant role in sustainable development.

Recent changes in global economy resulted; India is becoming one of the cheapest sourcing in the automotive map edging out knowing competitors like China, Mexico and Eastern Europe. In line with this, many multi-national industries (BMW, FORD, NISSAN) have identified India as a potential market for strong product growth and have started investing heavily by setting up manufacturing facilities and distribution centers (Mathiyazhagan and Noorul Haq 2013; Xu et al. 2013).

2. LITERATURE REVIEW

There are various concepts, definitions and overlapping views among the researchers and practitioners, but the central theme is still the same for all of them. Many researchers have approved upon high level of importance to the knowledge flow. Knowledge flow improves organisational performance through enabling communication between various stakeholders of organization. Reviews of the literature on the definitions of SSCM (Carter and Easton, 2011; Ahi and Searcy, 2013; Pagell and Shevchenko, 2014) propose that SSCM is the voluntary integration of social, economic and environmental considerations with the key inter organizational business systems to create a coordinated supply chain to effectively manage the material, information and capital flows associated with the procurement, production and distribution of products or services to fulfil short term and long term profitability, stakeholder requirements, competitiveness and resilience of the organization. Pagell and Schevchenko (2014) have

discussed that SSCM could be understood from a process point of view and in particular from a cycle and push/pull view. The cycle view focuses on embracing sustainability in procurement processes, manufacturing processes, replenishment processes and executing customer order processes. We can argue that the push/pull interface focuses on collaboration between suppliers and manufacturers. Therefore, SSCM can be understood as SCM focusing on maintaining environmental, economic, and social stability for long-term sustainable growth. Collaboration helps to commercialize and to ensure easy access to innovative technologies for the local and lower-tier suppliers in the supply chain (Vachon and Klassen, 2008; Dam and Petkova, 2014; Glover et al., 2014). Further, Chiou et al. (2011) discussed the impact of environmental collaboration of internal processes' environmental sustainability referring to benefits such as clean technologies, lower energy consumption, and material re-use. Grekova et al. (2016) suggest that environmental supplier collaboration can enhance the significant firm's performance both directly (Zhu et al., 2007; De Giovanni, 2012) and indirectly (Dyer and Singh, 1998), that is, by stimulating the firm to invest in and implement more sustainable processes that influence the firm's performance. Thus, we argue that strategic supplier collaboration is acute for the success of SSCM, and is considered as one of the drivers of SSCM. Colicchia et al. (2016) proposed a supply chain network design framework which involves the environmental impact of both transportation and warehousing activities in chocolate products. It was found that cost-driven network optimization may lead to beneficial effects for the environment with minor increase in distribution costs. The incremental cost can be offset by improving the environmental performance. Luthra, Garg and Haleem (2015) identified critical success factors (CSFs) and performance measures of green supply chain management (GSCM). Marshall et al. (2014) developed multidimensional conceptualization and measure of social and environmental supply chain management sustainability practices. Tappia et al. (2015) suggested a model to evaluate the energy consumption and environmental impact of automated warehousing solutions. Savino, Manzini, and Mazza (2015) discussed the integration of environmental concepts in the value chain approach, with a concurrent assessment of sustainability improvements and their economic impact of fruit supply chain. Gopal and Thakkar (2016) analysed sustainable supply chain (SSC) management practices using SEM for understanding the causality among the TBL dimensions (financial, social and environmental) for Indian automobile industry. Jia et al. (2015) analyzed and identified dominant SSCM practices in the mining and mineral industries using Interpretive structural modelling (ISM). Wuet al. (2016) proposed a comprehensive and quantitative method to understand the concept of SSCM and to assess its performance. Dubey et al. (2016) highlighted alternative methods research for

SSCM by providing a conceptual framework that explores SSCM drivers and their relationships. Esfahbodi et al. (2016) address the trade-offs between environmental and cost performance in SSCM especially in emerging economies. Ahmad et al. (2016) reviewed corporate sustainability reporting practices in accordance to SSC oil and gas industry. Ahmad et al. (2016) focused on the challenges in relation to the SSCM practices in industries. Esfahbodi et al. (2016) summarized the role of governance in the adoption of SSCM practices and investigated the performance gains of an organization with regard to both environment and economy. Hussain et al. (2016) provided a comprehensive framework on sustainability measurement with a practical approach for measuring and implementing SSCM practices in Arab countries. It is thus clear that many researchers have focused on the need for implementation of SSCM in firms, the benefits of adopting SSCM practices, and the impact of those practices on a firm's performance (Jia et al., 2015; Luthra et al., 2017). Wolf (2011) has argued that sustainability in supply chain networks can be achieved through appropriate collaboration. Sustainable supply chain management (SSCM) is now identified as a primary factor in promoting industrial sustainability (Tonelli, Evans, and Taticchi 2013). Gopal and Thakkar (2015) has revealed that adoption of environmental practices in Indian automobile organizations such as reduction of energy consumption, resource consumption, emissions and solid waste can result in significant improvements in their economic performance.

Wuet al. (2016) proposed a comprehensive and quantitative method to understand the concept of SSCM and to assess its performance. Ahmad et al. (2016a) reviewed corporate sustainability reporting practices in accordance to SSCM in the oil and gas industry. Ahmad Et al. (2016b) focused on the challenges in relation to the SSCM practice in industries. Govindan et al. (2014) analyzed the impact of SSCM practices using a three-dimensional deductive research based approach; they considered the three dimensions of sustainability through lean, resilient, and green supply chain management paradigms. Beske et al. (2014) critically analyzed SSCM practices associated with the food Industry and summarized how the practices allow companies to gain control over their supply Chain and to achieve a competitive advantage.

Ahi and Searcy (2013) have argued that SSCM is an extension of green supply chain management (GSCM) with the integration of social and economic factors along with environmental factors. GSCM is relatively new concept, which is gaining popularity among manufacturers and suppliers to improve the organizational environmental performance (Sarkis et al., 2011; Chang et al., 2013; Madaan and Mangla, 2015). GSCM has been recognized as a crucial part to encourage organizational sustainability (Sarkis et al., 2011; Rath, 2013). Research on GSCM has

been attracting keen interest across the globe in last few years and the same has recently grown in India (Mohanty and Prakash, 2014; Mangla et al., 2014; Luthra et al., 2015).

3. CONCLUSION

Analyze sustainable supply chain (SSC) management practices for industry and to identify the critical factors for its successful implementation. SSC has been frequently promoted as a means of improving business competitiveness. Indian automobile industry, faced with intense supply chain competition and rapid changes in customer demand patterns and pressures from governments and other stakeholder groups has been encouraged to increase its attention on adoption of sustainability practices. Sustainability has become a competitive advantage of the individual firm's supply chain. Critical Success Factors (CSFs) to implement Green Supply Chain Management (GSCM) towards sustainability taking into account the automobile industry of India. It is observed that there is potential for future research in strategic issues and general sustainable development studies in SSCM. There is a need for growth in SSCM-based studies because they demand the involvement of more stakeholders to take into account all three dimensions of sustainability while they adopt business decisions along the supply chain. Sustainable supply chain management (SSCM) practices using SEM for understanding the causality among the TBL dimensions for Indian automobile industry.

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Supplier Relationship Management and Selection Strategies – A Literature Review

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Abstract: Supplier Relationship Management (SRM), is strategic planning and managing of all interactions with suppliers to maximize its value. Its application varies from construction industries to healthcare system and investment banks to aviation industries. Several buyer-supplier relationship models, as well as supplier selection and evaluation strategies, have been documented by many academicians and researchers. In this paper, through a comprehensive literature review of over 30 published papers, different theoretical models, empirical data and conclusions were analysed relating to SRM to find its role in establishing better supplier relationships. These journal articles were searched by using the keyword “supplier relationship management,” in databases of Mendeley Library, ProQuest, EBSCO and Google Scholar. This paper reviews the academic literature on different relationship models, supplier evaluation, and selection strategies to discuss its implications in different situations. It also describes the dominant factors responsible for buyer-supplier relationships such trust and power. Finally, conclusions have been drawn which can be validated by various researchers and can help practitioners in industries.

Keywords: Supplier Relationship Management, Supplier Performance, Supplier Selection

1. INTRODUCTION

In recent years, the management of strategic relationships between buyer-supplier has received increasing interest. Supplier relationship management (SRM) as defined by (Akamp and Müller, 2013) is the practice of planning, implementing, developing and monitoring company relationship with the current and potential supplier. Main management activities of supplier management are supplier selection and evaluation, supplier monitoring, supplier development and supplier integration. Supplier selection is regarded as the cornerstone of successful purchasing and supply management to maintain and enhance the competitive edge (Abdollahi et al., 2015). Articles on Supplier selection show quality as most popular factor followed by delivery, price, manufacturing capability, service, management, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment (Thakur and Anbanandam, 2015).

Moeller et al., (2006) described the benefits of SRM Base as 1) Better Supplier Base, 2) Cope with significant problems easily, 3) Act better coordinated and more consistent, and 4) Enhance value creation for customers. Therefore, SRM is a comprehensive approach which enhances cooperation (business relationship level), coordination (process level), and communication (information systems level) between the company and its suppliers to continuously increase efficiency and efficacy of collaboration and concurrently enhance quality, security, and innovation (Mettler and Rohner, 2009).

This paper is organized in the following manner. The next section discusses the methodology used to identify, choose and analyse existing research studies on supplier relationship management and supplier selection strategies.

The analysis revealed dominant themes in the research on SRM and its relationship with supplier selection which are presented in the subsequent section. While a majority of research studies have attempted to inspect the buyer-supplier relationship, some have also examined the factors that affect the supplier relationship management systems. The paper presents some such challenges and future research directions that are discussed in the literature. The last section details conclusion of this study.

2. METHODOLOGY

Using the keyword “supplier relationship management” and “supplier selection,” journal articles were searched for journal articles in Mendeley Library, ProQuest, EBSCO and Google Scholar. The keyword was found either in the title or the abstracts of the paper. In Google Scholar, top hundred results were considered. The search on Google scholar was limited to the abstract and the title of the respective document. The articles found in searches was scrutinized by the list of articles in ABDC Journals and Schimago Journals. Over 30 articles were identified published between 2000 and 2016. The findings are presented below from the analysis of the papers reviewed. The authors combine several categories that were used to analyse the articles as given below.

Preliminary Analysis

Authorship: Most of the articles reviewed had multiple authors and the average lies between two and three. From the 30 papers reviewed, each paper has around 40 references. It adds up to more than 1200 references in total. About 50% of the articles reviewed are published in 2012 or later. Less than five articles are published before 2007.

Nature of Study: About 50% of the papers reviewed had a specific country context such as India, China, Switzerland, USA, Japan, United Kingdom, Netherlands, Finland, and Malaysia. Most of the papers were descriptive, a few were diagnostic or experimental, and others were case studies. The majority of papers used literature reviews to generate hypothesis and the conducted surveys and interviews to verify them.

Theories Utilised: Few research studies mentioned the theories which they applied in the context of supplier relationship management to generate the hypothesis. Some of these are Social Exchange Theory (SET), Grey Theory, Evolutionary Game Theory (EGT), Intellectual Capital (IC) Theories, Resource Dependence Theory (RDT), Transaction cost analysis (TCA), and Game Theory.

Research Methodologies Used: Different studies were classified according to the dominant research method and data sources such as secondary data, survey, case study or a combination of these. About ten articles were conceptual or theory development papers based on literature reviews; about six papers were based on primary case studies; another five studies were based on experimentally collecting data through questionnaires and then analyzing the data.

3. DOMINANT THEMES

One of the critical objectives of a systematic review of literature is to assimilate the key findings of the different studies and identify common themes of research. The purpose of this study is to consolidate perspectives on supplier relationship management and supplier selection. In-depth and iterative analysis of the papers helped us evolve four dominant themes namely, buyer-supplier relationships, supplier selection strategies, supplier evaluation strategies and supplier development strategy. The chosen topics reflect both quantitative and qualitative emphasis of the papers reviewed rather than a complete mapping of all possible variables of interest. The items relate to issues and factors which are associated with SRM presented as higher-order constructs operationalized through lower-level elements. We introduce two of the themes i.e. buyer supplier relationships and supplier selection in this paper, categorize the research studies reviewed under each one and present brief summaries of the studies. Given the space constraints, the studies presented

are reflective of the themes, although not purely representative.

3.1 Buyer-Supplier Relationship

In their contribution, (Wieteska Grażyna, 2016) described how companies should develop relationships with suppliers while facing high market volatility. It focused on flexibility and adaptability in the context of Supplier Relationship Management (SRM). Flexibility in supply chain results in effective response to the changes in supply, demand, and products. Adaptability is built up in the context of adjusting to significant environmental changes. Flexibility in relations can be achieved through Flexible Purchasing and Supplier Flexibility.

To identify the possible obstacles to the SRM integration is the central theme of (Oghazi et al., 2016), and he strives to provides solution suggestions to overcome these barriers. In this regard, the survey of the literature and subsequent analyses of the empirical findings represent that the SRM process integration can take place by the integration of its different sub-processes into strategic and operational characteristics. Strategic sub-processes describe the definition and the structure of the entire process whereas operational sub-processes refer to the executive phase of the process. In this context, the lack of goal congruence, commitment, and trust among the manufacturer and its supplier are the main potential barriers to the SRM integration.

According to (Soh et al., 2016), the seven dimensions that are commonly used in literature to denote buyer-supplier relationships (BSRs) are trust, involvement, business understanding, communication, commitment, information sharing and knowledge. Trust most is essential in BSR. Factors that affect trust: commitments, communication effectiveness, cooperation, and transparency. The findings reveal Supplier Quality (SQ) and Supplier Commitment (SC) have direct significant relationships with Supplier Performance (SP). It also reveals that no mediating effects of BSR upon the relationships between Supplier Engagement (SE) and Supplier Infrastructure (SI) to Supplier Performance (SP).

Ji et al., (2015) studied the changing of cooperation tendency among multi-stakeholders (buyers and suppliers). The Evolutionary Game Theory (EGT) is adopted to describe the phase of further evaluation by analysing green costs and its benefits to players. Results implied that recycling capability is a crucial factor for the cooperation tendency among multi-stakeholders in the long-run. Green purchasing relationships among multi-stakeholders will influence the payoffs of the suppliers and manufacturers (buyers) in a two-tier supply chain.

In the following article, (Anni-Kaisa Kähkönen et al., 2015) empirically examine the relationships between value-

creating activities and buyer's dependence, and to determine what kind of supplier relationship management activities might decrease or increase the dependence. The results of the study indicate that the value-creating activities of inter-firm learning and early supplier involvement in buyer-supplier relationships improve the buyer's dependence on its suppliers, whereas a supplier orientation does not. From this study, it could be implied that the firms should weigh the pros (value creation) and cons (dependence) and develop management practices and relationship strategies based on those.

Identification of four main categories of both buyer and supplier attractiveness plays an important role in the article of (Tanskanen and Aminoff, 2015). These are: 1) economic-based, 2) behaviour-based, 3) resource-based, and 4) bridging-based attractiveness. They found economic- and behaviour-based attractiveness present in all dyads, while resource- and bridging-based attractiveness are emphasized when the strategic intention has more explorative elements and when the aim is to leverage the dyadic relationship in developing businesses outside the dyad.

Exploring the key supplier management (KSM) phenomenon (Ivens et al., 2013) discusses: how should it be organized, what are the (organizational) implications, and which benefits can be realized? KSM deals with the question how to analyse, plan, manage, and control interactions with these key suppliers.

Rezaei and Ortt, (2013) designed a rule-based approach to segment the suppliers of a firm based on two overarching dimensions that capture these available segmentation criteria. Another methodological contribution of the paper is to develop and apply a general sensitivity analysis procedure for fuzzy rule-based systems. This analysis is used to identify the most crucial supplier capabilities and willingness criteria and to formulate better supplier development strategies. A fuzzy rule-based system is formed of four functional blocks: knowledge base, decision-making unit, fuzzification interface, and defuzzification interface.

Main focus of (Jeong et al., 2013) in their article is on SCM in manufactured housing (MH) industry and an SRM Framework called MSROM is developed. Critical issues identified in SCM are Variable supplier Lead time and consistent safety stock level and a poor supplier evaluation process these issues are solved by MSROM framework and others specific Optimisation model. Framework for MSROM has to main subsystems: Material Sourcing process and Material control process. Results showed that the proposed system was more effective in controlling supplier lead time.

Akamp and Müller, (2013) investigates which measures of supplier management could advance supplier performance and buyer satisfaction. They proposed a structural equation model which was analysed using Partial Least Squares (PLS). The conceptual model takes supplier selection and evaluation, supplier monitoring, supplier development, and supplier integration as independent variables while supplier performance and buyer satisfaction being dependent variables. The results show that mainly cooperative activities such as supplier development and supplier integration are effective while, supplier monitoring does not seem to have a positive influence on supplier performance.

Bemelmans et al., (2012) shed light on obstacles to, and opportunities for, increasing the effectiveness of construction firms in managing buyer-supplier relationships. More specifically, the focus was on assessing the maturity level of buyer-supplier relationship management by construction firms. Aspects important in determining the effectiveness of buyer-supplier relationship management for a buying company includes optimizing supply base in terms of both the number and the quality of its suppliers, attention towards managing a buying company's portfolio of suppliers, deciding to what extent suppliers have to be integrated into their own processes, and attention to developing suppliers, on the basis of an ongoing monitoring of their performance. The impeding factors can be summarized as the lack of formalization, documentation, and communication (both internally and with suppliers) linked to the various policies, plans, processes and measurement systems that form part of the management of buyer-supplier relationships.

In the following paper, (Liu et al., 2010) developed a 2X2 relationship quality (RQ) matrix based on levels of mutual trust and commitment between both buyers and suppliers and explore the use of control mechanism. The research also tests the matrix and hypothesis proposed using the cluster, ANCOVA and SEM analysis. Based on the matrix different levels of trust and commitment can be developed namely the buddy, relier, arm's-length and initiative.

Svante Andersson and Per Servais, (2010) reviewed international industrial purchasing and marketing literature on portfolio models, to develop portfolio models for buyers' and sellers' international strategies, and to consolidate the models so that both the buyer and seller perspectives are dealt with simultaneously. He stated five product-related basic dimensions for buying situations: (importance, complexity, familiarity, innovativeness, and frequency) and three buyer-seller interaction-related dimensions (familiarity, dependence, and depth of interaction). These dimensions are used to develop a portfolio model of supplier relationship management and a marketing management model for supplier strategies. This study also examines how the different marketing management strategies fit with different supply strategies

and buying situations. The author concluded that to find a fit between buyers' and sellers' international strategies, the parties have to negotiate.

In this article, (Griffith and Lusch, 2008) determined how the individual elements of procedural justice influence the long-term orientation of a channel partner. Procedural justice refers to the perceived equity in the policies and procedures used within the relationship for resolving disputes and allocating outcomes. From the analysis it is implied that more open communication (bilateral communication, explanation) may not increase long-term orientation if the channel relationship doesn't become more reliable (i.e., improved consistency and credibility) and/or unless treatment of channel partners (interactional norms) is enhanced, and/ or develop policies that integrate the interests of their channel partner (voice).

Ounnar et al., (2007) contributed to the improvement of customer-supplier relationship is a decentralized self-organized control model based on the concept of Holon. Holon is the decision-making centre linked with the production system of the entity such as 'product', 'resource', 'order' and 'staff' (PROSA). In this model, the decision system controls a group of actors' operations who are in a partnership. In this paper, in particular, Analytic Hierarchy Process (AHP) for the evaluation of the suppliers' network is discussed. It allows a supplier to become an intelligent production unit able to operate in self-organization with other companies.

Aim of (Moeller et al., 2006) is at the development of a Framework for Supplier Relationship Management. For this purpose, they adapted and applied insights from Customer Relationship Management (CRM) as well as existing findings in supplier management literature. According to them, SRM can be subdivided into the following three main and sequential phases: Out-Supplier Management, In-Supplier Management, and In-Supplier Dissolution Management.

In their contribution, (Hwan-Yann Su et al., 2013) explores how partnerships can be enhanced through making transparent Intellectual Capital (IC) information to partners in the supply chain setting. IC refers to the sum of all intangible knowledge resources – the sum of all individual and organisational knowledge and capabilities – a firm can utilize for competitive advantage. Providing information comprising two components of IC transparency – the transparency of essential business characteristics and the transparency of relationship atmosphere – produces higher supply chain partner trust, satisfaction, and commitment than not providing that information.

Jiang et al., (2011) seeks to present empirical evidence about the effects of trust and dependence in business relationships in the construction industry. They test the

extent to which trust and dependence act as antecedents to four dimensions identified from the literature as being important determinants of relationship quality: commitment, communication, satisfaction, and long-term orientation. Main conclusion that one gets from this research is that Trust has more significant impact on relationship consequences (commitment, communication, satisfaction and long-term orientation) than dependence.

Identification of criteria for achieving efficient contractor-supplier relations for long-term relationships with suppliers and continuous cost-reductions play a crucial role in the article of (Mikael Frödell, 2011). These criterions can be divided into four groups: attributes of the relationship, communication behaviour, conflict resolution, and commodity/supplier selection process formalization. This study found that the most eminent enablers are total cost focus, aligned core values as well as the willingness and capability for collaboration and development.

Petersen et al., (2008) used resource dependency theory (RDT) to examine the circumstance in which a supplier has increasing levels of power above the buyer, such that the supplier may have little motivation to yield control or withhold the exercise of this potential power. Managerial strategies are also explored that a buyer may implement to mitigate the influence of supplier power on the creation of relational capital within the relationship. The results of the study imply that dependency, socialization processes, supplier integration, and relational capital have a more complicated set of interrelationships that form a vibrant and dynamic context for the study of buyer-supplier relationships.

Giving an overview of opportunism (Hawkins et al., 2008) described two critical theories of opportunism namely Transaction cost analysis (TCA) and Social exchange theory (SET). Opportunism is an aggressive selfishness that disregards the impact of the firm's action on others example stealing, cheating, etc. Antecedents and consequences are also discussed with proposed paths for further research. Opportunism in procurement exchanges for services will be lower when contractual and relational governance is implemented.

Huang et al., (2011) examines the influence of guanxi (i.e., interpersonal social ties) between supplier salespersons and retail buyers in the retail industry in China. Applying a mixed-method study combining both qualitative and quantitative stages, they found that guanxi between supplier salespersons and retail buyers may not improve retailer-supplier relationship quality. Furthermore, their results show that guanxi between supplier salespersons and retail buyers may decrease the positive effect of supplier role performance on retailer satisfaction.

Identification and analysis factors that inhibit or facilitate the sourcing processes with indigenous Chinese firms is the central theme of (Giannakis et al., 2012), and it explores the effect of distinct Chinese cultural characteristics on the nature of supplier relationship management. Factors that promote or inhibit supplier relationships' management: sourcing processes, governance structure, interaction process and multiple regression. The research also shows that guanxi has significantly positive relationship with suppliers' satisfaction with the supplier relationships.

3.2 Supplier Selection Strategies

Based on our investigation, we summarize five strategies that had been used for supplier evaluation and selection. Readers can find the typical usage of these techniques in the corresponding articles.

In the following article, (Thakur and Anbanandam, 2015) proposed a Multi-Attribute Decision Making (MADM) model based on the grey theory for optimal supplier selection in the context of Indian banking industry. This optimal selection helps a lot to provide the best supplier for "optimizing digital banking" services under uncertainty. Grey theory includes five significant parts: grey prediction; grey relational analysis; grey decision; grey programming; and grey.

In their paper, (Abdollahi et al., 2015) described a theoretical framework for supplier selection based on the two groups of "lean" and "agile" suppliers is presented and a guideline for supplier relationship management (SRM) for these suppliers has been proposed. To determine the precise interdependencies between the suggested criteria, fuzzy decision making trial and evaluation laboratory (DEMATEL) is applied to the problem. Moreover, Analytical network process (ANP) application finds the weight of each sub-criterion, and finally, Data envelopment analysis (DEA) approach is utilized to rank the suppliers regards to their score in each criterion.

Yeniyurt et al., (2013) found in their study that if a sourcing organization strives to achieve exceptional supplier working relations, it should be integrated across its geographic regions with knowledgeable global and local procurement personnel which effectively communicate with the company's suppliers, while working collectively in a coordinated manner to achieve a globally responsive supply chain.

Wu and Shen, (2006) developed a strategy-based planning process to guide user requirements determination. It focuses on problem structuring issues; i.e., the unstructured problems of the SRM domain. An analysis of buyer-supplier behaviour in developing a relationship with suppliers. The planning process includes three steps: define purchasing strategies, identify supplier selection criteria, and determine system requirements. Olsen and Ellram

model which includes four situations (namely Bottleneck, Strategic, Non-critical and Leverage) has more power in interpreting research findings. So it was chosen for the survey. This new approach fundamentally overcomes the impact of problem unstructured issues associated with SRM domain toward user requirements determination of e- SRM.

According to (Choy et al., 2003, 2004), there is an urgent need for developing an enterprise application integration (EAI) system for outsourced type manufacturers so that selection of appropriate suppliers can be made through a common Web-based platform. By doing so, customers' need can be directly related to suppliers' capability. This paper focuses on the integration of the Customer Relationship Management (CRM) and Supplier Relationship Management (SRM). By developing an Intelligent Supplier Relationship Management System (ISRMS) using Case-Based Reasoning, the author is making a system for potential supplier selection, and it is tested in Honeywell Consumer Products Limited. Case-Based Reasoning (CBR) is a method for solving Problems using previous similar situations from the case Database. Its Process uses 4 "Re's": Reuse, Retrieve, Revise and Retain. Its applications can be classified into two types- Classification Tasks and Synthesis Tasks. CBR can be applied in Planning, Design, Diagnosis of Diseases and customer service section. In ISRMS two CBR modules are present, Supplier selection and Help Desks.

4. THE CHALLENGES AND FUTURE RESEARCH DIRECTIONS

Research of (Oghazi et al., 2016) stated ten obstacles that can slow down and prevent the integration of SRM from occurring. These are the lack of trust, lack of communication and shared goals, lack of standard tools, lack of commitment, lack of willingness, specificities of the IT system, degree of formality, security barriers, inflexibility, and cost of integration.

Based on the systematic review we found the following directions for future researchers:

- Supplier development programs aimed at improving the flexibility of suppliers' production systems (WieteskaGrażyna, 2016).
- Use of grey theory for multiple-supplier selection in the manufacturing sector where one cannot always rely on a single supplier (Thakur and Anbanandam, 2015).
- Anni-KaisaKähkönen et al., (2015) suggested:
 - Examination of the effects of early supplier involvement, inter-firm learning and a supplier orientation on supply performance and company innovativeness.

- Identification the other value-creating components in business relationships, and control the firm-specific effects such as the duration of the relationship and the asymmetric sizes of business partners.
- An in-depth investigation into the association between dependence and relationship risk.
- Constraints related to establishing and maintaining contractor-supplier relationships within the construction industry (Mikael Frödell, 2011).
- Determination of optimum portfolio of relationship types between contractors and suppliers in the construction industry (Bemelmans et al., 2012).
- Examining whether the individual elements of procedural justice differ in importance over the duration of the relationship development process (Griffith and Lusch, 2008).
- Building a more precise conceptualization of key supplier relationships (KSM), and sharpening and deepening the link between KSM and other streams of literature, specifically for strategic management (Ivens et al., 2013).
- Influence of stakeholders (like local government, etc.) in Green Purchasing (Ji et al., 2015).

5. CONCLUSION

This paper provides a systematic literature review of articles published from 2000 to 2016 on the supplier relationship management and selection strategies. It aims to analyse the collected articles from two analytical aspects: buyer-supplier relationships and supplier selection. A total of 30 journal articles were carefully selected and reviewed in detail. We systematically summarized the SRM models and supplier evaluation techniques. This paper provides valuable knowledge accumulation about current studies and directions for future works.

This study has two major limitations. First, our review focuses on the application SRM and supplier selection. Other important aspects such as supplier development, were not involved in this review because of the limited research scope. Second, the reviewed articles were published from 2000 to 2016 and searched based on the keywords “supplier relationship management,” “supplier selection,” and “SRM.” Some articles published in late 2016, if any, may not be included in this review because of the limitation of reporting time. A future study could be expanded in scope.

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Criteria for Supplier Selection and Supplier Evaluation: A Literature Review

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Abstract: Supplier selection (SS) is currently a subject of great importance to organizations. SS and supplier evaluation (SE) is a multi-criterion decision making problem which includes both qualitative and quantitative criteria. These criteria affect on evaluation of performance of suppliers and decision-making process. In order to select the best suppliers it is necessary to make a trade-off between these tangible and intangible criteria some of which may conflict. This paper reviews the literature of SS and SE and the performance criteria from 1966 to till date related articles appearing in the international journals are collected and studied to answer the above mentioned questions or to accomplish the objectives of this paper. This paper identifies some of the important criteria of SS and SE. This paper also attempts to find few criteria as per their level of importance based on the occurrence listing and which evaluation criteria were paid more attentions?. These important criteria for SS and SE are namely cost, quality, performance etc.

Keywords: Supplier selection, SE, vendor selection, vendor evaluation, performance criteria.

1. INTRODUCTION

In today's competitive operating environment it is impossible to produce or assemble the products at lower cost with high quality without suitable suppliers. Thus, one of the most significant purchasing decisions is the selection and maintenance of a capable group of suppliers (Weber et al., 1991). Supplier selection and SE is the process of finding the suitable suppliers those are capable of supplying the buyer with the right quality products and/or services at the right price, in the right quantities and at the right time (Zhang et al. 2009). The environment for taking decision about suppliers and their capability to deliver the products is a complex activity, as it includes high levels of ambiguity and uncertainty, competing stakeholder values and complicated relationships as a result of multiple conflicting objectives (Watt et al. 2009). Organizations revealed that suppliers offering lower prices did not necessarily provide best quality or service performance. They also pointed out that SE can be a multi-objective decision of lowest cost, best quality and service performance (Che and Yang, 2007). Still the organizations have to make tradeoffs between these criteria. To select the appropriate suppliers, two aspects including importance degree of the selection criteria, and suppliers' performance with respect to these criteria are essential (Ordoobadi, 2009). SS and SE is considered to be much important because criteria used in the evaluation process depend from industry to industry as per the level of importance, therefore this paper contains the opinion of different authors about the level of importance for criteria of supplier selection. SS and SE is a typical multiple criteria

decision making problem that involves multiple criteria like qualitative and quantitative. So it becomes apparent that the supplier selection process should include a suitable number of criteria, based on which, the organizations would be able to select the most appropriate supplier for the product/assembly under consideration. Also there is no previous exclusive literature survey is available on SS and SE criteria. This paper attempts to identify the number of criteria of SS and SE through the literature review.

In this paper, we thoroughly collected the literature related with the keywords "supplier selection", "SE", "vendor selection", "vendor evaluation", "performance criteria" from academic databases including Science Direct, Emerald, Springer-Link Journals, IEEE Xplore. As per the span and keywords from academic databases we collected and reviewed 94 international journal articles published from 1966 to till date. This paper attempts to identify the various criteria of SS and SE, also to find the few key criteria as per the level of importance. The remainder of this paper is organized as follows: Section 2 presents detailed literature review of SS and SE criteria. This paper is concluded in including the suggestions for future works.

2. LITERATURE REVIEW

This paper reviewed the journal articles those are published in the academic databases i.e. Sciondirect, Emerald, Taylor & Francis and Springer. More than 94 papers were reviewed to achieve the above mentioned objective of this paper. Only articles that had been published on SS and SE, performance criteria for SS/SE. These articles were

collected from academic databases including Science Direct, Emerald, Taylor & Francis Journals and Springer. “Supplier selection,” “vendor selection,” “supplier evaluation,” “vendor Evaluation,” “performance criteria” used as keywords for search and the literatures that has been published till date were accepted. Conference articles,

master and doctoral dissertations, text books, unpublished articles and notes were keep out of this research only the related articles in international journals were accepted for review. Based on this research methodology 30 important SS/ SE criteria were finalized which are as follows

TABLE 1.1: Criteria and Representing Literatures

Criteria	Representing Literatures
Cost	Youssef et al, (1996), Sevkli et al., (2003), Dickson et al, (1978) O’Shaughnessy (1974), Wilson (1994), Dahel (2003), Dickson (1966), Choy & Hartley (1996), Verma & Pullman (1998), Krause et al, (2000), Tracey & Tan (2001), Wang et al, (2010), Cardozo & Cagley (1971)
Quality	Pearson & Ellram (1995), Youssef et al, (1996), Sevkli et al, (2003), Sarkis & Talluri (2002), Chen & Chen (2006), Dickson et al, (1978) O’Shaughnessy (1974), Wilson (1994), Dickson (1966), Dahel (2003), Verma & Pullman (1998), Krause et al, (2000) Tracey & Tan (2001), Humphreys et al., (2003), Wang et al, (2010)
On time delivery or delivery performance	Sevkli et al, (2003), Sarkis & Talluri (2002), Dickson et al, (1978) O’Shaughnessy (1974), Wilson (1994), Dahel (2003), Dickson (1966), Verma & Pullman (1998), Krause et al, (2000), Tracey & Tan (2001), Wang et al, (2010), Cardozo & Cagley (1971), Lamberson et al.(1976), Monczka et al.(1981), Browning et al.(1983), Buffa & Jackson(1983), Bender et al. (1985), Ansari & Modarress(1986), Hahn et al (1986), Soukup (1987)
Flexibility	Youssef et al, (1996), Sarkis & Talluri (2002), Choy & Hartley (1996), Verma & Pullman (1998), Krause et al, (2000), Humphreys et al., (2003), Güler(2008), Sarode et al. (2008), Sezhiya & Nambirajan (2010), Humphreys (2005), Wu et al., (2010), Mohanty & Gahan (2013)
Performance and reputation in industry	Li (2009), Sevkli et al, (2003), Dickson (1966), Cardozo & Cagley (1971), Lamberson et al.(1976), Monczka et al.(1981), Buffa & Jackson(1983), Güler(2008), Kannan and Tan (2003), Ng & Skitmore (1995), Ng (2010)
Production facilities and capacity,	Dickson (1966), Lamberson et al.(1976), Monczka et al.(1981), Browning et al.(1983), Bender et al. (1985), Hahn et al., (1986), Soukup (1987), Burton (1988), Chapman (1989), Pal & Kumar (2008), Ekici (2013)
Technical capability	Dickson (1966), Lamberson et al.(1976), Browning et al.(1983), Hahn et al., (1986), Soukup (1987), Burton (1988), Chakraborty & Banik (2005), Sezhiya & Nambirajan (2010), Ng (2010), Kim & Boo (2010)
Service	Sevkli et al, (2003), Dickson et al, (1978) O’Shaughnessy (1974), Wilson (1994), Choy & Hartley (1996), Bernard (1989), Shil (2010), Sarode et al. (2008), Wu and Olson (2008), Kannan and Tan (2003), Yang et al., (2013)
Environmental performance	Azzone & Bertele (1994), Azzone et al, (1997), Sevkli et al, (2003), Che et al, (2010), Humphreys et al., (2003), Jabbour & Jabbour (2009), Ng (2010), Mohanty & Gahan (2013), Humphreys et al., (2003)
Geographical location	Sevkli et al, (2003), Dickson (1966), Monczka et al.(1981), Ansari & Modarress(1986), Hahn et al., (1986), Soukup (1987), Burton (1988), Ng (2010), Kim & Boo (2010)
Attitude	Mohanty & Gahan (2013), Felix et al, (1994) Chan et al, (2008), Dickson (1966), Ansari & Modarress(1986), Soukup (1987), Yang et al., (2013),
Warranties and claim policies	Felix et al, (1994) Chan et al, (2008), , Dickson (1966), Min (1994), Ng (2010), Kim & Boo (2010),
Labour relation records	Felix et al, (1994) Chan et al, (2008), Chan et al, (2008), Dickson (1966), Monczka et al.(1981), Min (1994), Mohanty & Gahan (2013)
Communication	Toni & Nassimbeni (2001), Felix et al, (1994) Chan et al, (2008), , Dickson (1966),

Criteria	Representing Literatures
Responsiveness	Youssef et al, (1996), Sarode et al. (2008), Humphreys et., al (1998), Pal & Kumar (2008), Holweg (2005), Kim & Boo (2010)
Satisfactory order processing	Felix et al, (1994), Chan et al, (2008), Shil (2010), Humphreys et., al (1998), Mohanty & Gahan (2013)
Financial position	Lamberson et al., (1976), Monczka et al.(1981), Soukup (1987), , Sezhiya & Nambirajan (2010), Ng (2010)
Cultural similarity	Min (1994), Hsu et al., (2006), Felix et al, (1994) Chan et al, (2008)
Legal claims	Min (1994), Felix et al, (1994) Chan et al, (2008)
Ethical standards	Min (1994), Mohanty & Gahan (2013), Felix et al, (1994) Chan et al, (2008)
Packaging	Sevкли et al, (2003), Ansari & Modarress(1986), Burton (1988), Pal & Kumar (2008)
Political stability	Felix et al, (1994) Chan et al, (2008), Min (1994),
Corruption perception	Felix et al, (1994) Chan et al, (2008)
Currency stability	Felix et al, (1994) Chan et al, (2008)
GDP growth rate	Felix et al, (1994) Chan et al, (2008)
Ability to keep promises	Felix et al, (1994) Chan et al, (2008)
Prompt response to requests	Felix et al, (1994) Chan et al, (2008)
Attractive discounts	Felix et al, (1994) Chan et al, (2008)
Desire for business	Dickson (1966), Soukup (1987), Ng (2010),
Competitive environment	Pearson & Ellram (1995), Ng & Skitmore (1995),

3. CONCLUSION

SS is a crucial decision making problem which involves both qualitative and quantitative evaluation of multiple criteria under consideration. This paper summarizes the important criteria for SS. The role of SS process recently an important concern for industries since it reduces cost which leads to increase the profit and competitive advantage. However, there are many criteria that companies can decide and this makes it difficult to decide the importance of criteria for taking decision. This research is done in two phases. In first phase this literature review represents various important criteria for SS.

The second phase attempted to determine few important criteria based on occurrence listing, with some concluding remark. This literature review provides valuable information, knowledge and current studies about the criteria of SS and SE. This literature review attempts to provide an overview of the body of the 94 papers having SS and SE criteria, which are published in the academic databases Sciencedirect, Emerald and Taylor & Francis and Springer. After analysing the data it shows that most of the

researchers have worked on the MCDM techniques for SS/SE. No exclusive or extensive survey has been conducted for identifying the criteria of SS/SE with their level of importance.

This review illustrated that in early phase cost was the single criteria for taking decision about the SS. After this criteria like quality, on time delivery and service were gaining most of the importance for taking decision. Now a day along with these above mentioned criteria, it is required to focus on environmental performance of supplier. This paper also identified the important criteria based on the occurrence listing like cost, quality on time delivery, flexibility, production facilities, technical capability and performance in industry etc. Environmental performance, social performance and geographical location of supplier needs to be taken care with the important criteria like quality, on time delivery, service, cost etc. As a part of future scope, there is a need of identifying the importance of these criteria through the expert survey by industry experts or field practitioners for different sectors and types of industry.

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Humanitarian Supply Chain Management: An Overview

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Abstract: The purpose of this paper is to present a brief overview of the field of humanitarian supply chain management (HSCM). HSC is activated instantly after the happening of a disaster, with the intend of saving lives, alleviating suffering of the victims, and reducing the impact on the constancy of the society. The unpredictability of global emergency disaster and the risk of the plenty and timely delivery of the goods/services is the challenge in the relief operations. This paper presented HSC involvement in four phases of a disaster life cycle. HSC must focus to supply an appropriate level of resources, materials to disaster affected locations globally in order to curtail human suffering and loss of life. The paper also detailed role and responsibilities of different stakeholders in HSC.

Keywords: Humanitarian Supply Chain, Humanitarian Logistics, Logistics Providers, Disaster.

1. INTRODUCTION

The procurement, warehousing, transportation activities and infrastructure that are associated with acquiring and distributing relief materials are the primary components of a relief effort, with logistics making up 80 percent of humanitarian operations (Van Wassenhove, 2006). HSCM is the process of, implementing, planning and controlling the proficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of source to the point of utilization for the intention of

alleviating the suffering of affected people. The task includes a range of activities, including transport, preparedness, planning, warehousing, procurement, tracking and tracing, and customs clearance (Thomas and Kopczak, 2005). The HSC (Humanitarian Supply Chain), unlike the CSC (Commercial Supply Chain) does not have the usual supply chain stages like those of suppliers, manufacturers, distributors, retailers and customers. Instead, the humanitarian supply chain consists of donors, international agencies, International NGOs, local bodies and the consumers (Oloruntoba and Gray, 2006)



Fig. 1. A typical HSC, Source: Oloruntoba and Gray (2006)

Beamon (2004), Thomas and Kopczak (2005), and Van Wassenhove (2006) illustrate the unique character of the disaster relief atmosphere and evaluate humanitarian supply chains with the commercial supply chains. There are basic differences between commercial supply chains and HSC in terms of their, consumer and demand distinctiveness, strategic goals and environmental factors. The governing characteristics that bring additional complexity and unique challenges to HSC design are:

- i) Be short of of goods (supply, people, technology, transportation capacity, and money)
- ii) Suddenly uncertain demand occur in very large amounts and short lead times for a wide variety of supplies,
- iii) High stakes associated with adequate and timely delivery,

- iv) Unpredictability of demand, in terms of timing, location, type, and size,

2. DISASTER CLASSIFICATION

Natural Disaster Classification (Guha-Sapir, Annual Disaster Statistical Review 2015) as shown in the table No. 1 with the number of disasters occur in the year 2015. In the year 2015, natural disasters once again had a devastating impact on human society. Total 376 natural disasters occurred in the ear 2015 (330 disaster occur in the year 2014 (rise of 14%)) caused the death of 22, 765 people (2014's 7, 959). Disaster affected 110.3 million victims and caused US\$ 70.3 billion damages. The five most frequently disaster affected countries were China (36), USA (28), India (21), Philippines (15) and Indonesia (10), which results 30 % of total disasters occurs in 2015. Floods remain the most frequent natural disaster in 2015 in the world.

TABLE1: Natural Disaster Classification

Geophysical (29)	Hydrological (175)	Meteorological (127)	Climatological (45)	Biological	Extra Terrestrial
•Earthquake (21) •Volcanic activity (7)	•Flood (156) •Landslide •Wave action	•Storm (115) •Extreme temperature (12) •Fog	•Drought (34) •Wildfire (11) •Glacial Lake outburst	•Epidemics •Insect Infestation	•Space weather

TABLE 2: Categorizing Disasters, Source: Van Wassenhove (2006)

Disaster type ↓ →	Natural disaster	Man-made disaster
Sudden on set disaster	Earthquake, Hurricane, Tornado, Tsunami	Chemical leaks, Terrorist attack
Slow on set disaster	Famine, Draught,	Political crisis, Refugees crisis

3. DISASTER LIFE CYCLE

There is rise in natural and man-made disasters and the victims affected by them have also increased in last few years. In the last decades, the area of disaster management and HSCM has gained significantly attention, and there are a number of literature review article in these area. Altay and Green (2006) have distinct four phases of a disaster life cycle: mitigation, preparedness, response, and recovery.

Mitigation: The mitigation phase is related to actions to reduce or diminish the potential impact of disasters. Preventing future occurrence, emergencies or minimizing their effects. Includes any activities that avoid an emergency, reduce the chance of an emergency happening, or reduce the damaging effects of unavoidable emergencies. This phase includes activities that avoid a disaster emergency, reduce the likelihood of occurrence of a disaster, or reduce the damaging effects of inevitable hazards. Mitigation activities should be considered long ahead of an emergency.

Preparedness: The preparedness stage is related to activities carried out before a disaster in preparation for the suitable responses. Preparing to handle an emergency. Includes plans or preparations made to save lives, rescue operations and to help response. Preparedness phase takes place before an emergency happens. This phase comprises developing plans for what to do, who to call, or where to go for help before an event occurs; actions that will recover your chances of successfully dealing with a crisis.

Response: Response is putting the preparedness plans into action. Response activities take place during an emergency. The main aim of a disaster response phase is rapid relief action (supplying emergency food, water, medicine, shelter, etc.) in the disaster affected areas, to minimize suffering,

losses and death. To safely response a disaster operation in an emergency condition is the major challenge. It comprises actions taken to save lives and avoid further property damage in an emergency situation.

Recovery: The recovery phase usually involves long-term activities to recover the losses occurs due to disaster. It consists of actions taken to return to a normal or an even safer situation following an emergency. Recovery activities take place after a disaster occurs.

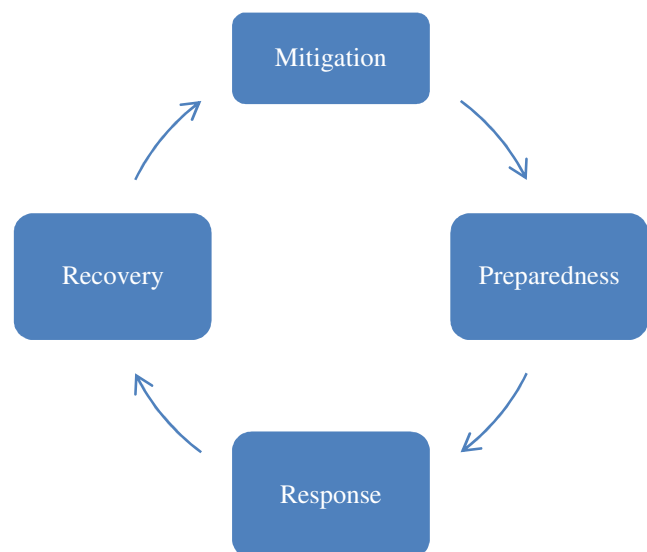


Fig. 2. Disaster Life Cycle, Source: Altay and Green (2006)

4. STAKEHOLDERS IN HSCM

Humanitarian logistics (HL) involve different parties, including governments, military, non-governmental organizations and aid agencies that differ widely in structure, size, aims, and knowledge (Van Wassenhove, 2006; Argollo da Costa et al., 2012). When major natural or man made disasters strike, international non-governmental organizations (NGOs), UN agencies, intergovernmental humanitarian organizations (HOs), national societies, governmental organizations, military institutions, and many others logistic service provider's move quickly to provide relief. United Nations bodies, local and international non-governmental organizations (NGOs) and host governments, as well as donors, military and logistics service providers are all concerned in one form or another. A number of the

operative bodies tend to specialize in rescue operation like camp management, medical care or food, water and sanitation (Jahre and Spens, 2007).

In humanitarian supply chains (HSC) donors and beneficiaries are both customers (Oloruntoba and Gray, 2009; Charles et al., 2010). HSC is a more complex structure than in a commercial supply chain, where suppliers are being paid and customers pay for the goods and services they receive. Performance measurement in particular becomes difficult, as various stakeholder groups measured performance in different ways. Table 3 detail roles and responsibilities of stakeholders. There is a lack of coordination in disaster relief logistics and HSC where combined actions among different international organizations are required (Kovacs et al., 2010).

TABLE 3: Roles and responsibilities of stakeholders

S. No.	Stakeholders	Roles/ Responsibilities
1	NGO's	To give the supports to humanitarian operation based on its role. NGO gave financial humanitarian aid in cash as well as in material form to support the operation, it collect the financial from consumers, employee and provider to support the operation.
2	Government	It mobilizes resources and they the power to authorize humanitarian operations in disaster affected regions.
3	Donor's	Donors give financial support to fund in humanitarian aid operations.
4	Military	A very significant player since soldiers are called upon to offer primary assistance, for example: food supply, hospital and camp installation.
5	Logistics provider	It assists HSC during disaster.
6	Aid agencies	Agencies to fund relief operations.

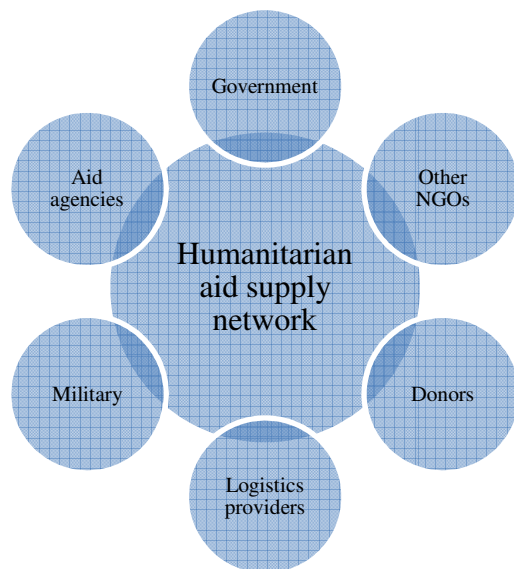


Fig. 3. Actors of supply network of humanitarian aid,
Source: Kovács and Spens (2007)

5. COMMERCIAL AND HSC

There are important differences between commercial supply chain and humanitarian supply chain (Oloruntoba and Gray 2006). The commercial supply chain is fairly stable as compared to HSC. Commercial supply chain has the benefit of precedent demand to forecast future demand. This means that commercial supply chain operates in a predictable environment, while humanitarian supply chain work in highly unpredictable environment. Table 4 list the difference between commercial supply chain and humanitarian supply chain.

TABLE 4: Difference between Commercial SC and HSC

Characteristic	Commercial supply chain	Humanitarian supply chain
Supply/Supplier	• Determined suppliers. • Supplier know the consumer	• It is difficult to select particular supplier. • Demand vary

Characteristic	Commercial supply chain	Humanitarian supply chain
	demand. • Systematic collection and performance monitoring	during the response phase of disaster.
Organization involved	• Well join with each other. • Having long-term relationship	• Unknown and voluntary partnership. • Relationship develops during the relief operations.
Demand/ Requirement	• Stable demand. • Precedent data can be used to predict the order.	• Mostly unstable demand. • Extremely unstable demand with time • Need quick assessment and information. • No generalized technique available
Network design	• Moderately stable	• Uncertain and unstable

6. CONCLUSION

After the Tsunami in 2004, HSCM have received significant concentration from both the humanitarian practitioners and academicians. A typical HSC required support from the government, aid agencies individual donors, international aid agencies and non-governmental organizations (NGOs). This article detailed role and responsibilities of the various stakeholders that helps in a humanitarian operation to provide relief in disaster affected areas. Due to unpredictable demand, location and type of disaster, there is vast difference between commercial supply chain and humanitarian supply chain as discuss in the article.

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Measuring Service Quality of Retail Outlets: An Empirical Investigation in Northern part of Tamil Nadu

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Abstract: This present work attempts to measure the service quality and its impact on customer's satisfaction in retail outlets of Chennai city. The instrument was designed to measure the perception of customers on the quality of service offered by retail outlets in Chennai. After a comprehensive review of literature and based on the brainstorming with experts in retail management and industry, an attempt has been made to conceptualize five quality constructs pertaining to service quality and develop an instrument, from the customers' perspective, in order to measure the service quality of retail outlet. The following are five dimensions under this model: (a) Infrastructure facilities (b) Management Responsibility (c) Employee and Customer Interaction (d) problem-solving, and (e) Business policy. This study has applied the stratified random sampling method to obtain the responses from shoppers of supermarkets in Northern part of Tamil Nadu, and it is disproportionately distributed. In the light of literature review, the retail service quality model is found to be the most suitable for measuring service quality. The results of the study show that the retail service quality has a positive correlation with customer satisfaction.

Keywords: Customer Satisfaction, Service Quality, Retail Service Quality Model, Retail Service Quality Scale

1. INTRODUCTION

For the past few years, retail sector has been experiencing the highest growth rate in terms of revenues in many countries as well as India. Retailing is the world largest private sector contributing to 8% of GDP and its employee one six of labor force. It contributes 10% of GDP and its second largest sector next to agriculture which provides maximum employment to the people. Today the quality of products and services consumed is of great importance. It is widely accepted that surviving in difficult and competitive conditions of a market economy requires good quality production. To understand and assess the results of efforts realized for good quality production, quality should be measurable..

2. MEASURES OF RETAIL SERVICE QUALITY

Service quality in retailing is different from any other product/service environment (Finn, 2004). Because of the unique nature of retail service, improvements and measurements of quality in retailing cannot be approached in the same way as that of the services perspective. In retail service, it is necessary to look at quality from the perspective of services as well as goods and derive a set of items that accurately measure this construct (Mehta *et al.*, 2000). For this reason, Dabholkar *et al.* (1996) developed and empirically validated the Retail Service Quality Scale (RSQS) to capture dimensions important to retail customers based on the triangulation qualitative research technique. They conducted qualitative research using three different methodologies - phenomenological interviews, exploratory depth interviews, and tracking the customer through the

store. Combining these qualitative findings with the existing literature and SERVQUAL, Dabholkar *et al.* (1996) proposed that retail service quality has a hierarchical factor structure comprising five basic dimensions, namely 'physical aspects', 'reliability', 'personal interaction', 'problem solving', and 'policy', with first three basic dimension having two sub-dimensions each and overall service quality as a second order factor. The sub-dimensions of the basic dimension 'Infrastructure' are: 'appearance' and 'Convenience'; the sub-dimensions of the basic dimension 'Management Responsibility' are: 'promises' and 'doing it right'; and the sub-dimensions of the basic dimension 'personal interaction' are: 'inspiring confidence' and 'courteousness/helpful'.

3. LITERATURE REVIEW

Parikh (2006) said that "As retailing develops in India, retail outlets in India will have to improve the quality of their services significantly in order to compete successfully in the global marketplace. It is, therefore very important to know how customers evaluate service quality and what can be done to measure and improve it. Azhagan & Nagarajan (2011) analyzed that "most of the customers prefer Retail sector because of more Tangibles and Empathy towards its customers. In order to retain and attract new customers, the organized retail sector should improve customer's service level and should provide assurance towards its customer." Singh (2013) stated that "In retail outlet service quality is having a significant influence on purchasing and repurchasing decisions, positive word of mouth as well as on complaining behavior in retailing". William & Prabakar

(2012) concluded that “The customer perception of retail service quality is an important segment to the emerging and the existing retailers in the market as the study reveals that perception of service quality influenced by the various nature with various customers even some of the general factors like Personal interaction, Infrastructure are the dimensions on of the customer perception remains constant and common to all the customer on a majority basis so the retail outlets have to frame their own strategies In order to attract the customers on a longer basis” .Kumar.R & Barani (2012) said that “service quality has long been accepted as the most basic marketing tool for retailers to differentiate their retail offers, create competitive advantage and to enhance the customers’ shopping experience. Nonetheless, maintaining excellent service quality within the stores is no simple task” U. Dineshkumar, P.Vikkraman (2012) found in their study that “ retail outlets provide better quality of service and most of the customers are satisfied with the quality of service provided by the retail outlets.” Kumar.R & Barani (2012a) identified in their study that “tangibles, reliability, responsiveness, competence, credibility, accessibility and customer knowledge are positively related to customer satisfaction. However, only four variables have significant effect on customer satisfaction.

4. OBJECTIVES OF THE STUDY

The main objective of the study is to find out the significant impact of retail service quality on customer satisfaction among retail outlets in Northern part of Tamil Nadu . Further, the secondary objectives are; to find out significant relationship between retail service quality and customer satisfaction; finally to suggest the retail outlets to frame the marketing strategies which will enhance the retail service quality and customer satisfaction.

5.1 Retail Service Quality and the Instrument

Dabholkar, Thorpe and Rentz (1996) proposed that retail service quality has a hierarchical factor structure. While different researchers think of retail service quality at different levels. Dabholkar, Thorpe and Rentz (1996) proposed five dimensions—physical aspects, reliability, personal interaction, problem solving, and policy. They also expanded sub-dimensions of each dimension to combine related attributes into sub-groups. The instrument was designed to measure the perception of customers on the quality of service offered by retail outlets in Chennai. After a comprehensive review of literature and based on the brainstorming with experts in retail management and industry, an attempt has been made to conceptualize five quality constructs pertaining to service quality and develop an instrument, from the customers' perspective, in order to measure the service quality of retail outlet. The following are five dimensions under this model: (a) Infrastructure facilities (b) Management Responsibility (c) Employee and Customer Interaction (d) problem-solving, and (e) Business

policy . They also expanded sub-dimensions of each dimension to combine related attributes into sub-groups. This study has applied the stratified random sampling method to obtain the responses from shoppers of supermarkets in Chennai city, and it is disproportionately distributed.

In the light of literature review, the retail service quality model is found to be the most suitable for measuring service quality. Five dimensions are defined as follows Infrastructure facilities :Physical facilities, equipment, and appearance personnel Management Responsibility: The ability to perform the promised service dependably and accurately Employee and Customer Interaction: retail store personnel are courteous, helpful, and inspire confidence Problem solving - retail store personnel are capable to handle returns and exchanges, customers’ problems and complaints.Policy - retail store’s policy on merchandise quality, parking, operation hours, and credit cards These five dimensions were expected to be distinct, but highly correlated. Three of the five basic dimensions of RSQS have two sub dimensions each. RSQS includes 27 items which of 17 items were extracted from SERVQUAL and 10 items developed from literature review and their qualitative research.

5.2. Hypotheses of the Study

The following hypotheses are formulated in this study:

H1: There is a significant impact of retail service quality on customer satisfaction

H1a: There is a significant impact of physical aspects in the retail service quality on customer satisfaction

H1b: There is a significant impact of reliability in the retail service quality on customer satisfaction

H1c: There is a significant impact of personal interaction in the retail service quality on customer satisfaction

H1d: There is a significant impact of problem solving in the retail service quality on customer satisfaction

H1e: There is a significant impact of policy in retail service quality on customer satisfaction

H2: There is a significant relationship between retail service quality and customer satisfaction

H1a: There is a significant relationship between Infrastructure in the retail service quality and customer satisfaction

H1b: There is a significant relationship between Management Responsibility in the retail service quality and customer satisfaction

H1c: There is a significant relationship between personal interactions in the retail service quality and customer satisfaction

H1d: There is a significant relationship between problem solving in the retail service quality and customer satisfaction

H1e: There is a significant relationship between policy in retail service quality and customer satisfaction

6 METHODOLOGY

6.1. Research Model

Quantitative study has been focused to answer the research question as what extent retail service quality influences on the customer satisfaction. In which, retail service quality is viewed as an independent variable and customer satisfaction is considered as the dependent variable.

$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \epsilon_i$
According to the above model, we can construct the new research model for the study.

$CS = \beta_0 + \beta_1 IF + \beta_2 MR + \beta_3 ECI + \beta_4 PS + \beta_5 PO + \epsilon_i$

Where:

CS = Dependent Variable (Customer Satisfaction)

β_0 = Intercept

β_1 = Population slope **β_2** = Population slope **β_3** = Population slope **β_4** = Population slope **β_5** = Population slope

IF = Independent variable (Infrastructure facilities) **MR** = Independent variable (Management Responsibility)

ECI = Independent variable (Employee- Customer Interaction) **PS** = Independent variable (Problem Solving)

PO = Independent variable (Policy) **ϵ_i** = Random Error

6.2. Study Design and Methods

6.2.1. Sample

The population of this study is the consumers of retail outlets in Chennai city. The most leading retail outlets were selected for the study and data were collected in Chennai city. Consumers of 16 Retail outlets were randomly selected to distribute the questionnaire. Systematic quasi-random

sampling method was used to select the sample of the study. This sampling method was chosen because it permits analysis of possible selection bias or error (Ndubisi, 2006). The data were collected on 12th of June 2017 from 10.00 a.m. to 4.00 p.m. The structured questionnaire was given to two consumers in every one hour who shopped at retail outlets and who confirmed their willingness to respond to the questionnaire. They were selected on the basis of systematic sampling technique.

6.2.2. Study Variables, Questionnaire Design and Data Collection

The RSQS questionnaire developed by Dabholkar, Thorpe and Rentz (2006) was used as the data collection instrument. The questionnaire has been slightly modified as it translated into Tamil to ensure suitability for the research context and it mainly consisted with three parts. Part A considers the respondent's personal profile and part B consists of 28 items relating to retail service quality in supermarkets and one item relating to overall customer satisfaction. One item was excluded from the original RSQS which consisted with 27 items. The fact was proved once the questionnaire was examined for the face validity by two academics who are experts in marketing and consultancy and four store managers from each of four brands of supermarket chains. Part C contained with two open ended questions, one was to know the leading reasons for consumers to retail outlet and the other one was to know consumers' suggestions to improve the retail service quality. A seven-point Likert scale from '1-strongly disagree' to '7-strongly agree' was used to measure the items. The questionnaires were distributed to 175 respondents from 16 outlet chains in Chennai. Out of 175, 160 completed questionnaires were selected for the final analysis after deleting 15 incomplete records with an effective response rate of 91.4% of the total sample.

6.2.3. The Reliability Statistics

To examine reliability of the scale dimensions, the Cronbach's Alpha was calculated, as it considered as the most widely accepted reliability measure. Table 2 provides the Cronbach's Alpha (α) for the five

Retail Service Quality Dimensions and Items Used in the Study with the Reliability Measures

Sl.No	Items	Dimension	Cronbach's Alpha
1	This store has modern-looking equipment and fixtures	Infrastructure facilities	0.764
2	The physical facilities at this store are visually appealing.		
3	Materials associated with this store's service (such as shopping bags, catalogs or statements) are visually appealing.		
4	This store has clean, attractive and convenient public areas		
	(restrooms, fitting rooms).		

Sl.No	Items	Dimension	Cronbach's Alpha
5	The store layout makes it easy for you to find what you need.	Management Responsibility	0.772
6	The store layout makes it easy for you to move around in the store.		
7	When this store promises to do something by a certain time,		
	it will do so.		
8	This store provides its services at the time it promises to do so		
9	This store performs the service right the first time		
10	This store has merchandises available when you want it.	Employee - Customer Interaction	0.746
11	This store insists on error-free sales transactions and records		
12	Employees in this store have the knowledge to answer your questions.		
13	The behavior of employees in this store instills confidence in you.		
14	You feel safe in their transactions with this store.		
15	Employees in this store give prompt service to you		
16	Employees in this store tell you exactly when services will be performed		
17	Employees in this store are never too busy to respond to your requests		
18	This store gives you individual attention.		
19	Employees in this store are consistently courteous with you		
20	Employees in this store treat you courteously on the telephone.		
21	This store willingly handles returns and exchanges	Problem solving	0.725
22	When you have a problem, this store shows a sincere interest in solving it.		
23	Employees of this store are able to handle your complaints directly and immediately		
24	This store offers high quality merchandise	Policy	0.739
25	This store provides plenty of convenient parking for customers		
26	This store has operating hours convenient to all their customers.		
27	This store accepts most major credit cards.		

7.1. Correlation Analysis

	Infrastructure facilities	Management Responsibility:	Employee - Customer Interaction	Problem solving	Policy	Retail Service Quality	Customer Satisfaction
Infrastructure facilities	1	0.494	0.600	0.621	0.510	.821	0.712
Management Responsibility		1	0.626	0.582	0.341	0.789	0.729
Employee and Customer Interaction			1	0.746	0.236	0.838	0.820
Problem solving				1	0.226	0.836	0.768
Policy					1	0.580	0.424
Retail Service Quality						1	0.894
Customer Satisfaction							1

Purpose of the correlation analysis is to find out the significant relationship between retail service quality and customer satisfaction. Further, it is utilized to find out the relationship between the dimensions or factors influencing on retail service quality as Infrastructure facilities, Management Responsibility, Employee-Customer Interaction, problem solving & policy and customer satisfaction. According to the analysis, retail service quality is positively associated with customer satisfaction, further,

strong positive association has been found, which is also in the significant level ($P < 0.05$). Meantime, all the dimensions which have been taken as the factors influencing on the retail service quality as Infrastructure facilities, Management Responsibility, Employee and Customer Interaction, problem solving & policy are also positively correlated. Except policy in the retail service quality, others factors have strong positive correlation with customer satisfaction

REGRESSION ANALYSIS

Variable	Beta Value	T- Value	P - Value	Adjusted R- Square	F- Value	Sig. Level
Constant		-2.234	.029	0.806	128.160	0.00
Infrastructure facilities	0.176	3.144	.002			
Management Responsibility	0.232	4.737	.000			
Employee- Customer Interaction	0.386	6.491	.000			
Problem solving	0.216	3.679	.000			
Policy	0.137	3.068	.000			

In this study, regression analysis has been utilized to find out the significant impact of retail service quality on customer satisfaction. Generally regression analysis is used to answer the question as what extent independent variables influence on the dependent variable. In this context, research question as what extent retail service quality influences on the customer satisfaction in the retail super markets is answered.

According to the analysis, 80 percent of the variation has been found which is in the significant level. It means that, customer satisfaction in the retail outlets is determined or influenced by the retail service quality. Further, customer satisfaction among retail super markets is also influenced by physical aspects, reliability, personal interactions, problem solving & policy in the retail service quality significantly.

8. CONCLUSIONS AND RECOMMENDATION

Retailer is an interface between upstream side and downstream customer of supply chain who insures the easy flow of goods to the customer. According to the results of the study, retail service quality in Chennai is positively associated with customer satisfaction. Further it revealed that all the dimensions have a strong positive correlation with customer satisfaction. It was also found that customer satisfaction among retail out is significantly influenced by the retail service quality. Policy in the retail service quality is measured by the measurements as high quality merchandise, convenient parking facilities, convenient operating hours and credit card acceptance. Especially, in the Chennai city, customers in the retail outlets have to face

the difficulties in terms of parking facilities and convenient operating hours. For these reasons, customer perception towards policy in retail service quality is in the moderate level comparing with the customer perception towards Infrastructure facilities, Management Responsibility, Employee - Customer Interaction, policy and problem solving in the retail service quality. Importantly, customer perception towards employees' knowledge & behavior, prompt service, individual attention, and complaint handling is in the highest level among the retail customers in the Chennai city. Due to that, retail service quality influences the customer satisfaction in the Chennai city significantly. Due to that, investments on the retail outlets aid to gain the return on investment and equity.

When the government frames the policies regarding to the fiscal and monetary, modern retail outlets should be considered through the concessions and other benefits. People in the Chennai city hold the better conditions in terms of demographic factors as income, social status, and life pattern etc. Studies in the other parts of Tamil Nadu might give the different findings. Before we come to the general conclusion in the Chennai context, studies among retail service quality should be taken in the various service industries, provinces and other places. Further, the concept like retail service quality should be connected with customer loyalty, customer retention and brand equity to get the more insights in the marketing practices of the retail outlets. Additionally, we suggested to the future researchers or scholars to carry the research on the factor analysis in order to find out the applicability of RSQS in the Chennai perspective.

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SECTION – III

OPERATIONS PLANNING AND CONTROL

Inventory Control Model with Varying Rate of Deterioration and Mixed Demand Pattern

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Abstract: This paper derives the optimal cycle time and total cost for an EPQ model with varying rate of deterioration and mixed demand pattern. Demand is inventory dependent during inventory buildup time and constant demand has been used for during inventory depletion period. Rate of deterioration is changing after particular time period. A numerical example has been provided to validate the model. The result of sensitivity analysis indicated that total cycle time and cost are sensitive to production rate, increase in deterioration rate and demand rate.

Keywords: EPQ, Mixed demand pattern, Varying rate of deterioration.

1. INTRODUCTION

In manufacturing sector, when items are produced internally instead of being obtained from an outside supplier, the EPQ model is often employed to determine the optimal production lot-size that minimizes overall production/inventory costs. The complexity of a resulting EPQ model depends on the assumptions one makes about various parameters of the inventory system. Among these features are demand types, actions for excess demand, production rates, treatment for imperfect quality items, minimal service level constraint, various cost parameters, and issuing policies when items are perishable. The classic EPQ model assumes that manufacturing facility functions perfectly during a production run. However, due to process deterioration or other factors, the generation of imperfect quality items is inevitable.

2. LITERATURE OF ECONOMIC PRODUCTION QUANTITY MODELS.

From product life cycle, demand rate will be constant only when product is in maturity stage. In the competitive scenario, higher stock of items attracts the customers to purchase more (Teng *et.al* 2005). Deterioration is the common phenomenon in the real production system of products like pharmaceuticals, food, flowers, vegetables etc. The effect of an imperfect production process, by assuming different rates of deterioration during the production process, on the optimal cycle time had been studied by (Rosenblatt and Lee, 1986). The EOQ model with power form of stock dependent demand for deteriorating items (Teng, *et.al* 2005), investigated that the shape parameter of the demand and selling price is highly sensitive to optimal solution. The impact of the random

machine failure on the EPQ model (Teng, *et.al* 2005) was that the demand function and purchase cost is positive and fluctuating with time. The production process can shift at random from in control to out of control state during production process. In such situation the items produced in out of control state deteriorate at higher rate than the normal rate, hence get consumed by demand under LIFO policy (Garry and Dah, 2006). Behrouz and Babak, developed economic production quantity (EPQ) model by considering both the depreciation cost of stored items and process quality cost. Depreciation cost and process quality cost was assumed to be continuous functions of holding time and of production run length. Yuan *et.al* (2011) derived the optimal manufacturing batch size and number of shipment with scrap using mathematical modeling and algebraic approach. Ata (2011) discussed EPQ model for multi products single machine with discrete delivery. Taleizadeh, Naja and Naiki focused on EPQ model with a production capacity limitation and a random defective production rate. Gede and Hui (2010) analyzed an EPQ model for deteriorating Items with stochastic machine unavailability and price-dependent demand. Jinn (2007), used time varying demand and cost to analysed EPQ model and characterize the influences of both demand and cost over the length of production run time and the economic production quantity. Hezari (2008) developed EPQ model by considering imperfect and defective items. Holding cost for defective items has not been considered. David *et. al* (2009) considered partial backordering with constant demand to study inventory model. Jiang tao (2009) consider a multi-item inventory system, where the vendor provides the retailer with delay in payment. Yao (2007) established a model for deteriorating items under delay in payment, in which the demand is a negative exponential function of

price. Jia (2009) reported a supply chain system with trade credit. Liao [6] established an EPQ model for deteriorating items with delay in payment. Ardak *et. al.* (2017) developed EPQ model by considering mixed demand pattern. Inventory dependent demand in inventory buildup time and constant demand during depletion period. Ardak & Borade (2017) considered time dependent holding cost to developed EPQ model.

Most of the inventory models considered various demand patterns like stock dependent demand, power form demand, ramp type of demand, time dependent demand, selling price dependent demand and exponential demand. It is well known that, the demand rate vary with change in inventory level. From the literature review, it is observed that the different demand pattern has not been discussed by any researcher so far on different time period. The present study may be significant in filling this gap since it aims to develop EPQ model by assuming demand as inventory dependent criteria during inventory buildup time and constant during inventory depletion period. This paper has five sections. Research motivation and literature is narrated in section 2. Section 3 contains notations and assumption. Methodology used to develop the model is discussed in section 4. Numerical and sensitivity analysis is discussed in section 5 and finally concluded in section 6

3. ASSUMPTION AND NOTATIONS

Following assumption and notations are used to develop the model.

3.1 Assumptions:-

The following assumptions are made in development of the model.

- The production rate is known and is constant.
- The production rate is greater than the demand.
- The demand is inventory level dependent in up time and constant in down time.
- Deterioration of the items is varying.
- Inventory holding cost is known and termed as constant.
- Deterioration of the items start as it enters into inventory.
- Shortages are not allowed.
- Every produced items needs inspection.

3.2 Notation

I_1 – Inventory level during production up time, I_2 – Inventory level during production down time, T_1 – Production up time. Maximum inventory buildup in this

time, T_2 –Production down time., T_2 –Production down time where rate of deterioration changes, P – Rate of production, D – Basic demand, θ – Basic rate of Deterioration, β – Increase in rate of deterioration, α – Inventory dependent consumption rate parameter., H – Holding cost per unit, C_i – Inspection cost per unit, T – Production cycle time., TC – Total cost., IC – Total Inspection cost, TCT – Total cost per unit time, TI – Total Inventory.

4. MODEL FORMULATION

This EPQ model considered inventory dependent demand and constant holding cost and different rate of deteriorating items. The production starts at time zero and inventory start to build up at the rate of $P - D$, which is the production rate minus consumption rate with deterioration up to time T_1 where the production process stops and the inventory on hand reaches its maximum level.. After T_1 , the inventory consumed under the action of demand and deterioration up to time T_2 . After time T_2 , the inventory level decreases with the constant consumption rate, D , but rate of deterioration increases until it becomes zero at time. The objective of this part of this research is to find the optimal inventory cycle time.

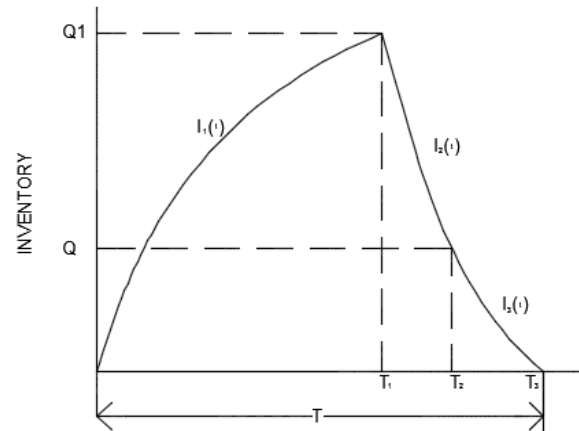


Fig. 1. Inventory System

As shown in fig.1, the production will start at $t = 0$, during the time period $(0, T_1)$ the inventory will gradually build up with constant deterioration. Later, production stops and buildup inventory is consumed to fulfill the demand. For the time period $(0, T_2)$, inventory will consumed under the action of constant demand and basic rate of deterioration. Maximum inventory will be at time $t = T_1$. For time period $(0, T_3)$, inventory get consumed under the action of constant demand and increase rate of deterioration. Production system can be described by the following differential equations.

$$\frac{dI_1(t)}{dt} = P - D - \alpha I_1(t) - \theta I_1(t) \quad 0 \leq t \leq T_1 \quad (1)$$

During time interval $(0, T_2)$, deterioration of items starts at basic rate. Hence the system is affected by the combined effect of constant demand and deterioration. Hence, the change in inventory level is governed by the following differential equation.

$$\frac{dl_2(t)}{dt} = -D - \theta l_2(t) \quad 0 \leq t \leq T_2 \quad (2)$$

In time interval $(0, T_3)$, demand rate is constant and rate of deterioration of items is at increase rate. Hence, the change in inventory level is governed by the following differential equation.

$$\frac{dl_3(t)}{dt} = -D - \beta l_3(t) \quad 0 \leq t \leq T_3 \quad (3)$$

Initial boundary conditions associated with this equations are, at $t = 0$, $I_1(t) = 0$, at $t = T_2$, $I_2(T_2) = Q$ and at $t = T_3$, $I_3(T_3) = 0$ the solution to above equations is as follows. These three equations are used in the derivation of our model.

$$I_1(t) = \frac{P-D}{\alpha+\theta} \left[1 - e^{-(\alpha+\theta)t} \right] \quad (4)$$

$$I_2(t) = \frac{-D}{\theta} + \left[Q + \frac{D}{\theta} \right] e^{\theta(T_2-t)} \quad (5)$$

$$I_3(t) = \frac{D}{\theta} \left[e^{\beta(T_3-t)} - 1 \right] \quad (6)$$

By using initial boundary conditions $I_3(0) = Q$ for equation 6

$$Q = \frac{D}{\beta} \left[e^{\beta(T_3)} - 1 \right] \\ = D \left[T_3 + \frac{\beta T_3^2}{2} \right] \quad (7)$$

By using boundary conditions $I_1(T_1) = I_2(0)$ and Eq.7 for equation 4 and 5,

$$\frac{P-D}{\alpha+\theta} \left[1 - e^{-(\alpha+\theta)T_1} \right] = \frac{-D}{\theta} + \left[Q + \frac{D}{\theta} \right] e^{\theta(T_2)} \\ T_2 = \frac{(P-D \times T_1)}{D} - T_3 - \frac{\beta T_3^2}{2} \quad (8)$$

Total Inventory is given by

$$TI = \int_0^{T_1} I_1(t) dt + \int_0^{T_2} I_2(t) dt + \int_0^{T_3} I_3(t) dt \quad (9)$$

Total Inventory holding cost is given by

$$IH = H \left[\int_0^{T_1} I_1(t) dt + \int_0^{T_2} I_2(t) dt + \int_0^{T_3} I_3(t) dt \right] \\ = H \left(\frac{P-D}{2} \times T_1^2 + D \left[T_3 + \frac{\beta T_3^2}{2} \right] \left(\frac{(P-D \times T_1)}{D} - T_3 - \frac{\beta T_3^2}{2} \right) + \frac{D}{2} \times T_3^2 \right) \quad (10)$$

All produced items need inspection, So inspection cost is given by,

$$IC = C_i \int_0^{T_1} I_1(t) dt \\ = C_i \left(\frac{P-D}{2} \times T_1^2 \right) \quad (11)$$

From equations 10 and 11.

Total cost = Set up cost + Holding cost + Inspection cost.

$$TC = A + IH + IC \quad (12)$$

$$= A + H \left(\frac{P-D}{2} \times T_1^2 + D \left[T_3 + \frac{\beta T_3^2}{2} \right] \left(\frac{(P-D \times T_1)}{D} - T_3 - \frac{\beta T_3^2}{2} \right) + \frac{D}{2} \times T_3^2 \right) + C_i \left(\frac{P-D}{2} \times T_1^2 \right)$$

$$\text{Production cycle time} = T = T_1 + T_2 + T_3 \quad (13)$$

$$T = T_1 + \frac{(P-D \times T_1)}{D} - T_3 - \frac{\beta T_3^2}{2} + T_3 \\ = T_1 \left(1 + \frac{P-D}{D} \right) - \frac{\beta T_3^2}{2} \quad (14)$$

Total cost per unit time is given by

$$TCT = \frac{TC}{T} \\ = \frac{A + K T_1^2 + K_1 T_1 T_3 - T_3^2 [K_2 + K_3 + K_4 T_1] - K_3 T_3^3 - K_5 T_3^4}{T_1 K_6 - \frac{\beta T_3^2}{2}} \quad (15)$$

Where,

$$K = (H + C_i) \frac{P-D}{2}, \quad K_1 = H(P-D), \quad K_2 = \frac{HD}{2}, \quad K_3 = \frac{HD\beta}{2}, \\ K_4 = \frac{H\beta(P-D)}{2}, \quad K_5 = \frac{HD\beta^2}{4}, \quad K_6 = 1 + \frac{P-D}{D}$$

Total cost per unit time is function of T_1 and T_3 . The optimum production up time can be derived by satisfying the equation.

$$\frac{dTCT}{dT_3} = 0 \text{ and } \frac{dTCT}{dT_1} = 0 \quad (16)$$

By solving equation No. 15 and 16 simultaneously optimum value of T_1 and T_3 can be obtained.

$$\frac{dTCT}{dT_3} = \frac{d}{dT_3} \left[\frac{A + KT_1^2 + K_1T_1T_3 - T_3^2[K_2 + K_3 + K_4T_1] - K_3T_3^3 - K_5T_3^4}{T_1K_6 - \frac{\beta}{2}T_3^2} \right] = 0$$

$$\frac{dTCT}{dT_1} = \frac{d}{dT_1} \left[\frac{A + KT_1^2 + K_1T_1T_3 - T_3^2[K_2 + K_3 + K_4T_1] - K_3T_3^3 - K_5T_3^4}{T_1K_6 - \frac{\beta}{2}T_3^2} \right] = 0$$

Ignoring higher power of T_3 & T_1 and after some approximation, following quadratic equation can be obtained.

$$T_3 = \sqrt{\frac{AK_6}{K_2K_6 + K_3K_6 - \frac{\beta}{2}K}} \quad (17)$$

$$T_1^2(K_1K_6) - T_1[2K_2K_6T_3 + 2K_3K_6T_3 + K\beta T_3] - A\beta T_3 = 0 \quad (18)$$

Closed form solution can be obtained by considering positive root of equation 18.

5. NUMERICAL AND SENSITIVITY ANALYSIS

Numerical example and sensitivity analysis has been carried out to validate the theoretical aspects. The numerical data is adopted from Ardak *et al.*(16) Let, $A = \text{Rs.}30$ per production cycle, $P = 2500$ units per unit time, $D = 1200$ units per unit time, $\alpha = 0.5$, $\theta = 0.1$, $a = 2$ $b = 1.5$. and $\beta = 0.2$ The optimum value of T_1 can be found. The optimum value of T_1 is 1.4. The optimum total cost per unit time is $TCT = \text{Rs.}2411$. Sensitivity analysis is carried out by changing each parameter by -40% to $+40\%$, taking one parameter at a time and keeping others unchanged.

TABLE 1: Sensitivity analysis of T_1

Parameters	Parameter changes							
	-40%		-20%		20%		40%	
	T_1	TCT	T_1	TCT	T_1	TCT	T_1	TCT
P	4.42	1794.77	1.99	1986.96	1.1	3015.83	0.96	3767.80
D	1.06	3745.65	1.21	2841.55	1.7	2236.12	2.14	2209.72
β	1.34	2330.63	1.37	2371.09	1.4	2450.42	1.46	2489.23
H	1.86	2209.04	1.58	2301.22	1.3	2525.52	1.17	2640.02
Ci	1.38	2155.99	1.39	2282.64	1.4	2541.15	1.42	2673.05

From figure 1, it can be commented that production up time is highly sensitive to production rate and demand rate. While production up time is slightly sensitive to deterioration rate and holding cost.

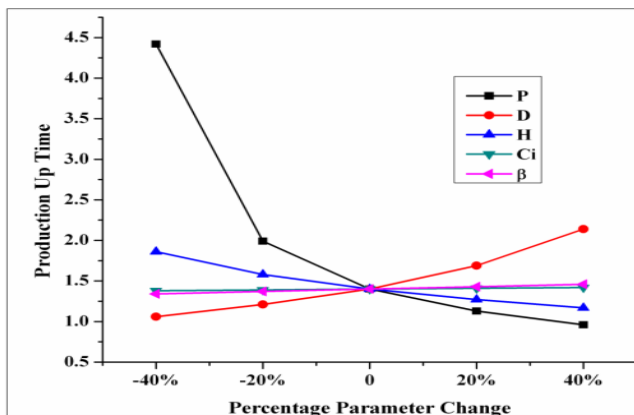


Fig. 1. Parameter change V/ T_1

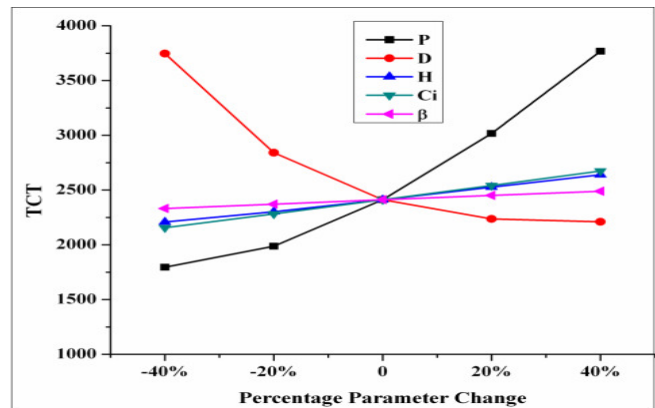


Fig. 2. Parameter change V/sTCT

For first 20% increases in production rate change in production up time is more as compared to last 20% change in production rate. This may be due to inventory dependent demand. Figure 2 indicates that TCT is highly sensitive to

demand rate and production rate. Increase in rate of deterioration also increases T_1 and TCT. This attracts attention of inventory managers.

6. CONCLUSION

In this study, theoretical EPQ model has been developed over an infinite time horizon. Some interesting observations are presented. During inventory buildup time, demand used was inventory dependent and during inventory depletion time it was constant. Sensitivity analysis shows that TCT as well as production up time are highly sensitive to production and demand rate. Increase in rate of deteriorations increases the TCT and optimum cycle time. This model can be useful for the inventory managers in decision making especially for the perishable items. The model can be further developed by considering different deterioration rate, production rate.

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Development of Simulation based Aggregate Production Plan for Manufacturing

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Abstract: An Aggregate production planning helps to balance the capacity and demand to minimize the overall cost with reference to inventory and labor levels, overtime, subcontracting, backordering levels and other resources. To generate the solutions, linear programming models are used. This paper presents the methodology to develop aggregate production plan by using Mathematical modeling using Linear Programming followed by Arena simulation software.

Keywords: Aggregate Production Planning, Manufacturing, Linear Programming, Simulation, ARENA.

1. INTRODUCTION

Every organization needs planning to operate the system. Every manufacturer need to satisfy consumer demands. This requires the efficient operation of a supply chain planning. At different levels of aggregation companies create several plans with the help of different planning horizons. The term aggregate production planning (APP) is medium-range capacity planning which typically covers a time horizon of 2 to 18 months. The aim of aggregate production planning is to achieve a production plan in which the organization's resources will be effectively utilized to satisfy the given demand. Aggregate production planning helps to balance the capacity and demand to minimize the overall cost with reference to inventory, labor levels, overtime, subcontracting, backordering levels and other resources. The Aggregate production planning is the big picture approach to planning. Aggregate production planning is high level planning activity in the production management system. This paper presents the methodology to develop aggregate production plan by using Mathematical modeling using Linear Programming followed by Arena simulation software.

2. LITERATURE REVIEW

Simulation is the imitation of the operation of a real-world process or system over time. Simulation is an attempt to model a real-life situation on a computer to study how the system works. By changing the variables, predictions may be made about the performance of the system. Many books and research papers deal with the general topic of simulation. There are several annual conferences exclusively dealing with the simulation technology, tools and applications.

Lin Pan and Brian H. Kleiner (2012), writes about today's aggregate planning, its objective, characteristic and techniques. In this paper, the brief introduction of aggregate

planning is given. AtthawitTechawiboonwong and PisalYenradee (2002), writes APP model and a guideline to develop an optimal aggregate production plan using the spreadsheet solver and the manufacturing case study presented to demonstrate how the guideline can be applied. Xueying T. et al. (2010), writes about the development and application of a simulation-based aggregate planning approach that facilitates modeling and coordination of a batch plant's supply chain. J.S. Smith (2003) has done a study on modeling and development aspects pertaining to manufacturing systems simulation. Heilala J. (2010) at winter simulation conference explains, the development of simulation based decision making system for customer driven manufacturing planning. Moradi and Schubert (2015) at Swedish Defense Research Agency explained Simulation-based decision support for evaluating operational planseffectively. Maciej Nowak (2013), studied a new approach for production aggregate planning problem is proposed. Gadinaikand Bilolikar (2015) explains how to improve performance parameters like resource utilization, delivery time and inventory for a batch type manufacturing system. Molly Arthur (2014) presented a paper Simulation-Based Decision Support System for JSF Production, explaining the modification done in the production schedule. Mourtzis D. and Bernidaki D. (2014), explains the challenges in Simulation of Manufacturing systems. Shirazi B. and I. Mahdavi (2010) explains Development of a Simulation-Based Intelligent Decision Support System for Flexible Manufacturing Systems. Negahban A., Smith J. (2013) did the literature review and survey on the simulation of manufacturing system design and operation. More than 300 papers are reviewed in this paper. Bai et al. (1996), use simulation to analyze the performance of production system under different control policies. The objective of the research was to evaluate the feasibility of using simulation for production control policy selection.

3. METHODOLOGY

The foremost concern of this research is to study how the production capacity can be improved by changing operating policies, for this we are using two methodologies. One is mathematical modeling and other is simulation methodology. The mathematical modelling involves the use of Linear Programming method in which a set of objective functions subjected to the set of constraints is solved. Our study deals with the minimization of overall cost of production, overtime, subcontracting and fluctuations in production. The constraints applied to the problem are related to regular production hours, demand, capacity of satisfying the maximum demand, limitation on the fluctuation of demand. The spreadsheet solver is used to solve the linear programming problem.

The basic assumptions considered are as follows:

- The forecast of the demand has been made for the next T periods.
- The model should provide a plan that minimizes the particular objective.
- The customer service is at utmost importance for the company. Therefore, the final inventory in month t should be high enough to guarantee high probability of meeting the demand in next month.
- The prime objective is to minimize total cost, which includes production cost, inventory cost and the cost involved in idle situations. Shortages are not allowed in this model, so the cost of delays in deliveries is not taken into consideration.
- The production is measured in production hours required for its completion.

The notations used in the model are as follows:

R_c^{pi}	=	the regular time production cost per labor-hour of i^{th} part,
E_c^{pi}	=	the overtime production cost per labor-hour of i^{th} part,
H_c^{pi}	=	the subcontractor production cost per labor-hour of i^{th} part,
K_c^{pi}	=	the inventory holding cost per month of one labor-hour of work of i^{th} part,
I_c^{pi}	=	the idle regular time production cost per labor-hour of i^{th} part,
D_c^{pi}	=	the cost delayed delivery per one production hour of i^{th} part,
R_t^{pi}	=	the regular time production hours scheduled in month t of i^{th} part,
E_t^{pi}	=	the overtime time production hours scheduled

in month t of i^{th} part,

H_t^{pi}	=	the subcontractor time production hours scheduled in month t of i^{th} part,
K_t^{pi}	=	the number of working hours stored in inventory at the end of month t of i^{th} part,
I_t^{pi}	=	the number of idle time regular production hours in month t of i^{th} part,
W_t^{pi}	=	the expected demand in month t (hours of production) of i^{th} part,
M_t^{pi}	=	the highest demand the company should be able to satisfy in month t (hours of production) of i^{th} part,
MR_t^{pi}	=	the maximum number of regular time hours in month t of i^{th} part,
ME_t^{pi}	=	the maximum number of overtime hours in month t of i^{th} part,
MH_t^{pi}	=	the maximum number of subcontractor hours in month t of i^{th} part,
a_t^{pi}	=	the reduction in the number of production hours scheduled in month t compared to the number of production hours scheduled in month t – 1 of i^{th} part,
b_t^{pi}	=	the increase in the number of production hours scheduled in month t compared to the number of production hours scheduled in month t – 1 of i^{th} part,
K_0	=	initial inventory,
T	=	The number of months in the planning horizon.
P	=	The number of parts under considerations
p_i	=	i^{th} part ($i = 1, \dots, P$)

The objective functions are:

$$f_1 - \text{Total cost: } f_1 = \sum_{t=1}^T \sum_{p=1}^P (R_c^{pi} R_t^{pi} + E_c^{pi} E_t^{pi} + H_c^{pi} H_t^{pi} + K_c^{pi} K_t^{pi} + I_c^{pi} I_t^{pi}) \quad 4.1$$

$$f_2 - \text{The total number of overtime production hours: } f_2 = \sum_{t=1}^T \sum_{p=1}^P (E_t^{pi}) \quad 4.2$$

$$f_3 - \text{The total number of subcontractor production hours: } \quad (4.3)$$

$$f_3 = \sum_{t=1}^T \sum_{p=1}^P (H_t^{pi})$$

The total fluctuations in production rates:

$$f_4 = \sum_{t=1}^T \sum_{p=1}^P (a_t^{pi} + H_t^{pi} + E_t^{pi}) \quad (4.4)$$

The constraints subjected to the objective functions are as follows:

$$K_{t-1}^{pi} + R_t^{pi} + H_t^{pi} + E_t^{pi} - K_t^{pi} = W_t^{pi} \quad (4.5)$$

$$K_{t-1}^{pi} + R_t^{pi} + H_t^{pi} + E_t^{pi} \geq M_t^{pi} \quad (4.6)$$

$$R_t^{pi} + I_t^{pi} = MR_t^{pi} \text{ for } t = 1, \dots, T \quad (4.7)$$

$$R_t^{pi} + H_t^{pi} + E_t^{pi} + a_t^{pi} - b_t^{pi} = R_{t-1}^{pi} + H_{t-1}^{pi} + E_{t-1}^{pi} \text{ for } t = 2, \dots, T \quad (4.8)$$

$$K_0^{pi} = K_1^{pi} = 0, a_1 = 0, b_1 = 0 \quad (4.9)$$

$$0 \leq R_t^{pi} \leq MR_t^{pi}, 0 \leq E_t^{pi} \leq ME_t^{pi}, 0 \leq H_t^{pi} \leq MH_t^{pi} \text{ for } t = 1, \dots, T \quad (4.10)$$

$$a_1 \geq 0, b_1 \geq 0, I_t \geq 0 \text{ for } t = 1, \dots, T \quad (4.11)$$

$p = 1, \dots, P \forall$ equations.

Here $P = 4$, as we considered 4 parts. These parts are regular parts.

As stated earlier, the research starts with forecasting the demand for T period followed by developing an aggregate production plan using linear programming approach. The study also helps to increase the utilization rate by reducing the idle situations and downtime.

The study is carried out in a company which produces manifold assemblies for AC's in cars. In recent days, the company finds it difficult to provide the demanded parts in said period. This in turns results in customer dissatisfaction. The aim of the study is to create the proper aggregate production plan in order to meet customer demand in said time.

3.1 Data Collection

For creating the model, most of the data taken was real time shop floor data which is collected by observation. It includes collecting the processing time on the resources per product which takes around 2 to 3 months of careful observation. Secondary data like layout of the plant of the facility, machines in the company, total manpower, were collected from senior members of the organization, while standards and product list were obtained from the company executives. Data collected are classified into Primary, Secondary and Tertiary type in table 1.

TABLE 1: Type of Data

Primary Data	Processing Time, Setup Time, Batch Size, Modification in Plant Layout, detailed Process Flow Diagram.
Secondary Data	Plant layout, Working Hours per day, Demand pattern, Number of resources, Material Information, Scheduled Maintenance.
Tertiary Data	Product List, Material Information, System Used, tool used, Standard used, throughput time.

For this, a company's manufacturing set up is modeled in ARENA i.e. virtual model is created. The model is studied and analyzed for various input situations. The results are tested and the solutions are formed. "ARENA Simulation Software" is used for creating the Manufacturing system's model shown in figure 1.

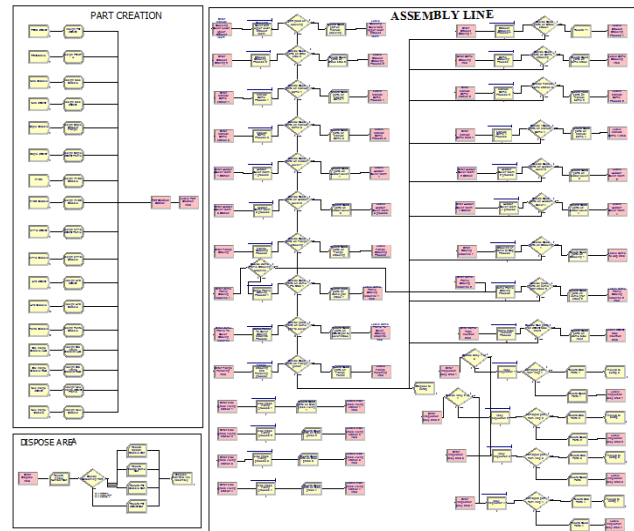


Fig. 1. ARENA Model of a firm

After studying the current scenario over which the company is working, it is found that, the company is unable to meet the demand level that customer wants. Also, few resources are bottlenecked. Some resources are found to have the utilization over 99.98% while some have 12%. There are some resources which are idle and having 0% utilization which leads to incompleteness of customer's orders. This unbalanced condition in utilization of resources leads to plan the entire production to balance the resource utilization as well complete the orders.

Now using anExcel Solver, the linear programming model is solved. The results obtained are fed in Arena and the new Scenario has been recorder. The process analyzer tool has been used to check the different scenarios.

4. RESULTS AND DISCUSSIONS

The company was struggling to fulfill the customer's demands. This caused serious customer dissatisfaction which further caused customer loss to the company. The forecasted demand and the result are shown in table no. 2 and 3 respectively. From the ARENA process analyzer, it is observed that some machines are over utilized, some are underutilized and some are idle which rectified after

implementing the plan produced from Linear Programming model. The first scenario is without any heuristic. From the next, the scenarios are made by implementing the LPP Plan. Results are shown in tables 4, fig. 3, and fig. 4. The results generated by the proposed method of aggregate production planning indicates that the model provides a promising approach to fulfill the efficient production planning objectives in a complex manufacturing system.

TABLE 2: Simulation, ARENA.

Sr. No.	Parts	Demand					
		M1	M2	M3	M4	M5	M6
1	Part 1	21250	13843	14814	16393	14814	12750
2	Part 2	20000	12800	14857	16229	14857	11657
3	Part 3	13714	7286	8143	9429	8143	8571
4	Part 4	16271	7657	8423	8327	8614	8614

TABLE 3: Results from Solver

It. No.	Mon.	PARTS											
		Part 1			Part 2			Part 3			Part 4		
		hrs.	parts	Cost	hrs.	Parts	Cost	hrs.	parts	Cost	hrs.	Parts	Cost
ITERATION 1	M1	175	21250	34870	170	16271	36789	160	13714	24500	170	16271	25280
	M2	114	13843		80	7657		85	7286		80	7657	
	M3	122	14814		88	8423		95	8143		88	8423	
	M4	135	16393		87	8327		110	9429		87	8327	
	M5	122	14814		90	8614		95	8143		90	8614	
	M6	105	12750		90	8614		100	8571		90	8614	
ITERATION 2	M1	70.23	8527	38234.56	84.18	8058	37902.24	71.55	6133	24560.06	84.18	8058	25399.3
	M2	69.4	8427		75	7179		70.81	6070		75	7179	
	M3	67.74	8226		64.94	6215		69.4	5949		64.94	6215	
	M4	65.25	7924		57.2	5475		67.35	5773		57.2	5475	
	M5	53.24	6465		46.03	4406		60.85	5216		46.03	4406	
	M6	49.3	5987		44.59	4268		57.51	4930		44.59	4268	
ITERATION 3	M1	75.43	9159	35095.01	87.5	8375	44835.32	76.69	6573	25275.32	87.5	8375	25612.19
	M2	74.35	9029		78.58	7521		75.53	6474		78.58	7521	
	M3	72.21	8768		67.85	6495		73.52	6302		67.85	6495	
	M4	68.99	8377		59.32	5678		71.25	6107		59.32	5678	
	M5	55.99	6799		47.76	4571		62.26	5336		47.76	4571	
	M6	49.43	6002		45.65	4370		57.72	4948		45.65	4370	
ITERATION 4	M1	155.37	18866	41406.05	122.17	11693	45317.32	165	14143	26205	122.17	11693	26538.89
	M2	80	9714		80	7657		80	6857		80	7657	
	M3	87.5	10625		87.5	8375		87.5	7500		87.5	8375	
	M4	85	10321		87.5	8375		85	7286		87.5	8375	
	M5	87.5	10625		90	8614		87.5	7500		90	8614	
	M6	85	10321		90	8614		85	7286		90	8614	

TABLE 4: Utilization Result in Different Iteration for month 1 (M1)

Sr. No.	Iterations	Machine 01	Machine 02	Machine 03	Machine 04	Machine 05	Machine 06	Machine 07	Machine 08	Machine 09	Machine 10
1	M1-01	0.7196	0.8006	0.1556	0.6668	0.6126	0.6612	0	0.5896	0.5172	0.9778
2	M1-02	0.3214	0.3675	0.0714	0.273	0.2734	0.271	0.3517	0.2707	0.2605	0.3317
3	M1-03	0.5332	0.3927	0.0764	0.2926	0.4537	0.2903	0.3648	0.2893	0.2706	0.3443
4	M1-04	0.6279	0.7997	0.1545	0.5931	0.5338	0.5881	0.5045	0.5851	0.3742	0.4759

The results are then fed into arena, and the resource utilization and the delivery schedule has been tested. Table no.3 and Figure no. 3 gives the utilization result from arena. Here, we observe that all the machine utilization is way

below 1 and greater than 0, i.e. the machines are not over utilized nor unutilized. Also Figure No.4 shows parts produced in different scenarios.

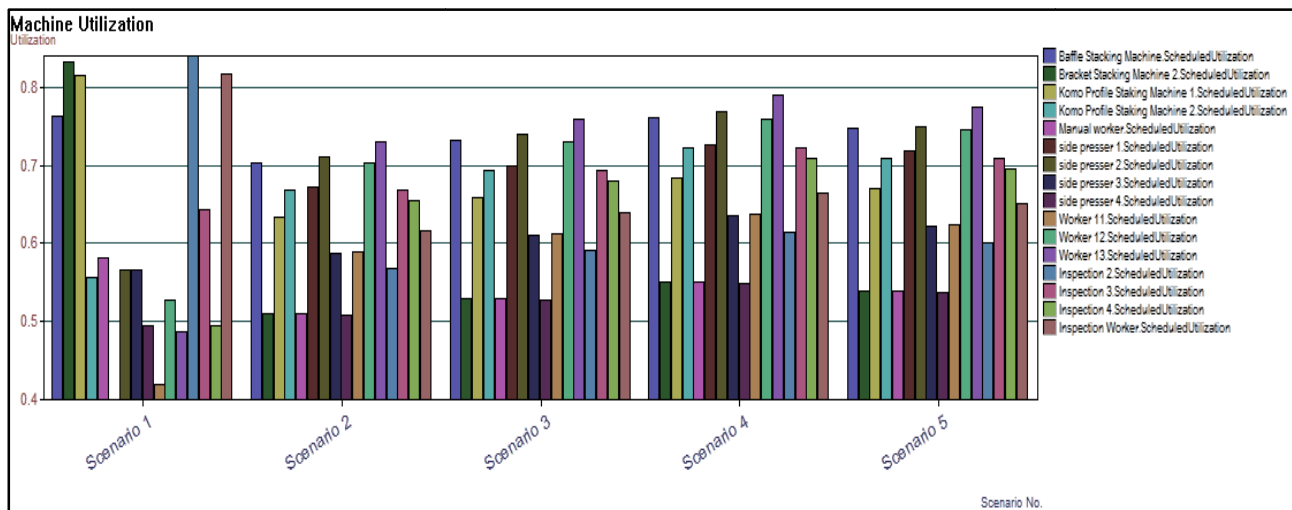


Fig. 2. Machine Utilization in Different Scenarios

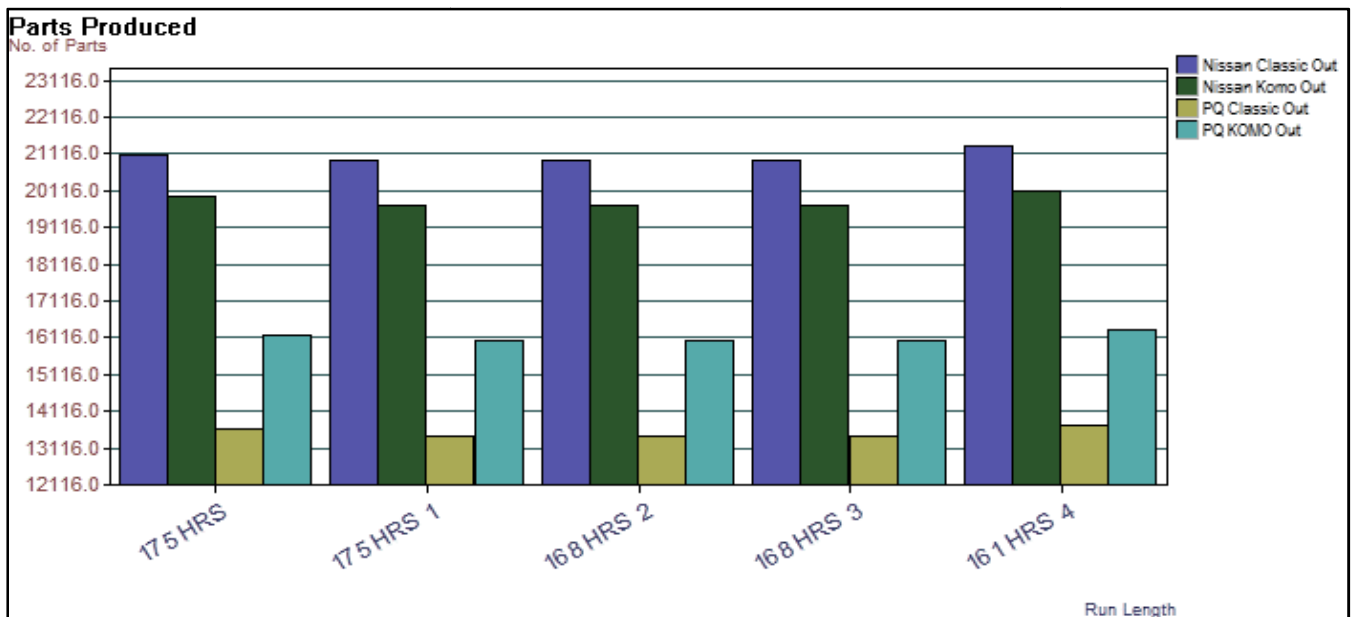


Fig. 3. Parts Produced in Different Scenarios vs. Run Length

5. CONCLUSION

The aim of Aggregate production planning is to achieve a production plan to meet fluctuating future demand in which organization's resources will be effectively utilized. This study helps to discover the lowest-cost plan. Also, Simulation model helps to check the various plans, its impact over the system and the best fit plan without disrupting the setup. By using Simulation, the future study in the field of waiting time behavior, new resources, their utilization and the status of inventory over them and layout changes can also be done. to test operational plans as to their robustness.

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An ANP Approach for the Assignment of Projects to Teams in an Organization

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Abstract: Every Organization deals with projects and there is a need for the organization to assign the right projects to the right teams which can handle the projects efficiently. After having a clear understanding of the projects and the team capabilities, Decision Maker underpins this assignment process. Multi criteria Decision Making offers a range of methods to come to an optimal solution for the same.

Keywords: Assignment model, Multi criteria decision making, AHP, ANP.

1. INTRODUCTION

Every Organization has a set of projects or tasks to complete in a certain time-period. These projects may be dealt with by the organization one by one or simultaneously. It depends on the functioning style of the Organization and the size of that organization in the market. In today's competitive world most of the organizations deal with multiple projects simultaneously. Thus, formulation of teams becomes an obvious step and the next bigger step and perhaps a critical step is the appropriate assignment of the projects to the teams. Any wrong decision in this assignment leads to delayed completion of projects or even become bottlenecks (in case the projects are a part of bigger projects) which could heavily impact the organization's reputation in an ever-un-stable market today.

Up until now, the assignment of projects to teams is done either randomly or depending on the past-experience of the decision maker. The projects being worked upon will have their own attributes and so will the teams. The attributes of the team will be holistically derived from those of its team members. So, it becomes unavoidable to consider the attributes of both projects and teams to get the right match between the two. Here is where Multi Criteria Decision Making plays a key role. Multi Criteria Decision Making (MCDM) is a tool in Operations Research. It considers multiple conflicting criteria or factors that need to be evaluated to make decisions. One of the main tools that MCDM offers under it is 'Analytic Hierarchy Process' or AHP.

In the AHP approach, the decision problem is structured hierarchically at different levels with each level consisting of a finite number of decision elements. The upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria. The weights of the criteria and the scores of the

alternatives, which are called local priorities, are considered as decision elements in the second step of the decision process. The decision-maker is required to provide his preferences by pair-wise comparisons, with respect to the weights and scores. But AHP has a set-back. It only considers decision making in a hierarchical structure. It does not account for those decision-making problems involving multiple criteria and alternatives with feedback and interdependence. In such cases, Analytic Network Process or ANP can be applied. Most of the MCDM techniques work well under the assumption of judgmental independence of criteria. ANP is one such MCDM techniques which considers the influence and dependence of the factors on each other.

This paper explores the relationships between the attributes of the projects and those of the teams and tries to come up with an optimal match between the two using ANP.

2. LITERATURE REVIEW

The problem consists of set of Teams that are supposed to perform a set of projects. It is given that each Team has a given capacity in terms of the maximum number of projects that can be allotted to the teams such that no team is left unassigned. This problem can be modelled as a Generalised Assignment model. Kuhn(1955) presented the Hungarian method where the number of tasks is equal to the number of employees and the goal is to minimize the total cost incurred. Chauvet et al.(2000) address two real life Bottleneck assignment problems in their paper. In both the cases the number of employees who should perform the task is significantly greater than the number of tasks to be performed. Jeonghwan et al.(2016) have proposed an approach based on the analytic network process (ANP) to rank a set of potential A&D candidates within a multivariate set of attributes systematically. A total of 25 criteria were identified and used to construct the ANP model in which the final selection is based on the resulting

priorities assigned to the A&D candidates. Beltrán et al. (2017) have studied the influence of stakeholders within a project using ANP to obtain an index for each stakeholder which represents his individual influence with respect to the rest of the stakeholders of the group. Hosseini et al. (2013) have explained how the various super matrices can be calculated by applying ANP to select the best strategy to reduce risks in a supply chain. Acar and Aplak (2016) have applied ANP to study the Multi-Objective and Multi-Criteria Vehicle Assignment Problem in a Security Organization scenario. Acar and Aplak have used the SuperDecisions software to find out the criteria weights and the performance values.

3. METHODOLOGY

The ANP (Saaty, 2001) is a generalisation of AHP. The problem in ANP is depicted and analysed as a network. The network structure is obtained because of the interdependence between the various criteria and the alternatives which are grouped into clusters depending on some common feature.

The methodology involves the following steps:

- STEP 1: Understanding the problem
- STEP 2: Formulation of ANP model
- STEP 3: Using the ANP software for the calculation of the main/sub Criteria weights.
- STEP 4: Evaluating the performance values (Using ANP software) of assigned projects for each team.
- STEP 5: Modelling the assignment and realising the optimal project assignment.

3.1 Understanding the Problem:

The problem being faced by the organisations is that they have to complete say, P projects simultaneously and the reigns of these projects are to be handed over to T teams (where, $P > T$) with different number of members in them. The Decision maker i.e.; the Team Manager randomly or at the least based on his past experience with the teams, assigns the projects to the teams. There are several problems that arise due to this random assignment. At times, one

team which is relatively better than others in some attributes may be handling most of the projects while the other teams may have relatively less work load. This hampers the efficiency of the teams and ultimately the organisation and may also cause delayed completion of the projects.

3.2 Formulation of ANP model:

Once the main goal is determined, the decision maker is approached for determining the criteria and sub criteria and the relationships and interdependencies among these factors is established. The ANP model has been obtained in Figure No 1. The study involves an illustrative case of 10 projects and 5 Teams.

3.3 Using the ANP software for the calculation of the main/sub Criteria weights:

After relations between criteria are revealed, the face to face interview is conducted with the decision maker and questions are asked in order to measure the pair-wise comparisons between criteria. The question of how many times a criterion is more important than the others has been answered with pairwise comparisons of criteria. Pairwise comparisons are formed in Super Decision software and each pairwise comparison is performed. The pairwise comparisons have been entered in the software using the Questionnaire Format. After all the pairwise comparisons are made, the Unweighted, weighted and Limit Super-matrices can be obtained from the Super -Decisions software. The limit super matrix of the model is obtained from the software is presented in Figure 2. Row values obtained from the limit super matrix give the priority coefficient to select the best alternatives.

The software then gives the local and global weights of each of the elements in all the clusters which are presented in Table No. 1. The local weights are the weights of each elements in their respective clusters whereas the global weights are the overall weights of the elements in the entire model. The global weights are considered for further calculation.

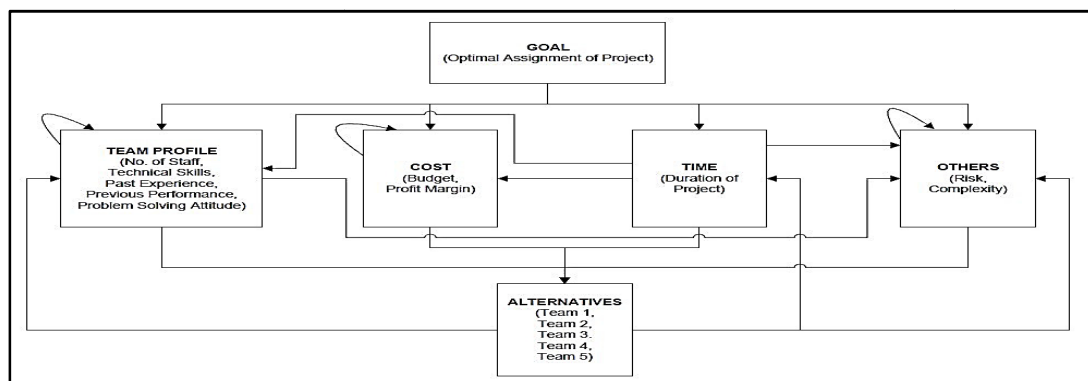


Fig. 1. ANP Model

GOAL NO	CONL NO	NUMBER	PAST EX	PREVIOUS	PROBLEM	TECHNIC	BUDGET	PROFIT	DURATIO	COMPLEX	RISK	TEAM 1	TEAM 2	TEAM 3	TEAM 4	TEAM 5
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165	0.02165
0.0000	0.0000	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047	0.13047
0.0000	0.0000	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871	0.02871
0.0000	0.0000	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828	0.03828
0.0000	0.0000	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310	0.24310
0.0000	0.0000	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336
0.0000	0.0000	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941	0.00941
0.0000	0.0000	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858	0.06858
0.0000	0.0000	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412	0.10412
0.0000	0.0000	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395	0.07395
0.0000	0.0000	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882	0.00882
0.0000	0.0000	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472	0.06472
0.0000	0.0000	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964	0.03964
0.0000	0.0000	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085	0.00085
0.0000	0.0000	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435	0.04435

Fig. 2. Limit Super-matrix

TABLE1. Local and Global Weights of Elements

CRITERIA	LOCAL WEIGHTS	GLOBAL WEIGHTS
Number of staff	0.04684	0.021649
Technical Skills	0.52594	0.243075
Previous Performance	0.06212	0.028713
Past Experience	0.028228	0.130470
Problem Solving Attitude	0.08282	0.038280
Budget	0.58678	0.013358
Profit Margin	0.41322	0.0094071
Duration of Project	1.00000	0.068580
Risks	0.41530	0.07395
Complexity	0.58470	0.10416

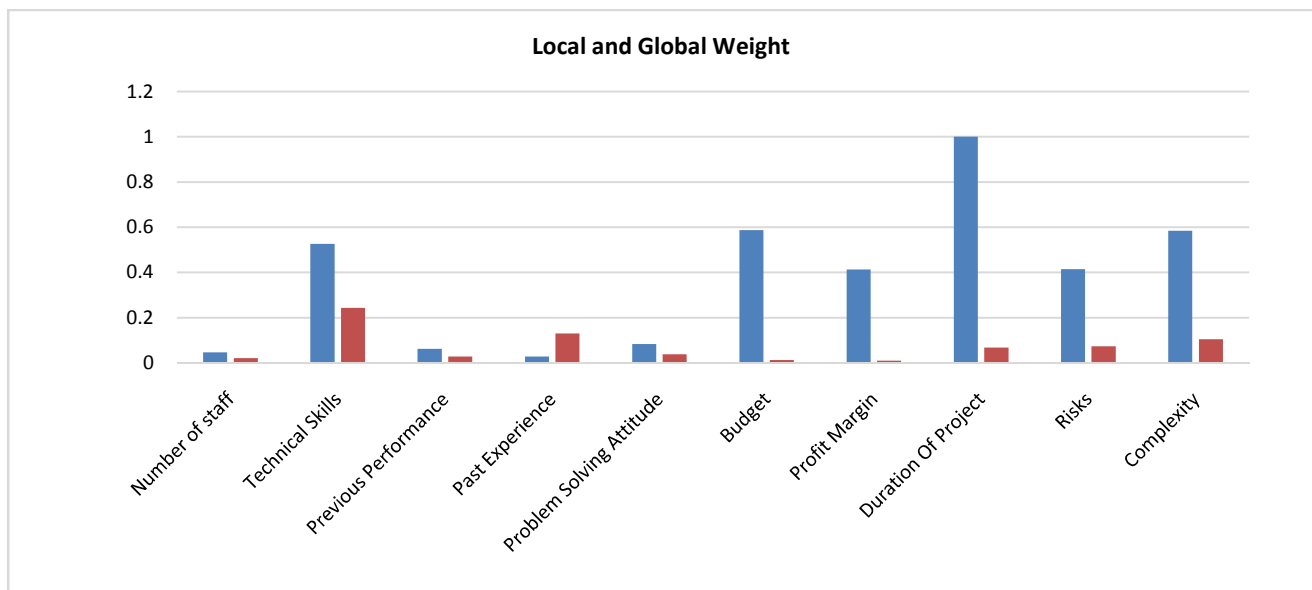


Fig. 3. Local and Global Weight

3.4: Evaluating the performance values (Using ANP software) of assigned projects for each team:

The performances of all alternatives against each project are evaluated under criteria by using the “ratings” section in ANP’s software. Standards of performance for each alternative is established for each criterion and the alternatives are rated one at a time with respect to each criterion using these standards. An illustrative example is shown in Figure No. 4. This Figure depicts the Performance Value of all the 5 Teams with respect to Team efficiency cluster for Project P1. Similarly, performance values (Priorities) of the teams with respect to each element in each cluster is obtained for each of the projects.

	Priorities	Totals	PAST EXPERIENCE 0.282276	PREVIOUS PERFORMANCE 0.062122	PROBLEM SOLVING 0.082820	TECHNICAL SKILL 0.525944	NUMBER OF STAFF 0.046838
TEAM 1	0.316426	0.969126	1ST PRIORITY	1ST PRIORITY	2ND PRIORITY	1ST PRIORITY	1ST PRIORITY
TEAM 2	0.273916	0.838929	2ND PRIORITY	3RD PRIORITY	1ST PRIORITY	1ST PRIORITY	2ND PRIORITY
TEAM 3	0.190366	0.583039	2ND PRIORITY	2ND PRIORITY	4TH PRIORITY	2ND PRIORITY	3RD PRIORITY
TEAM 4	0.099862	0.305848	4TH PRIORITY	5TH PRIORITY	4TH PRIORITY	3RD PRIORITY	4TH PRIORITY
TEAM 5	0.119430	0.365783	3RD PRIORITY	4TH PRIORITY	3RD PRIORITY	3RD PRIORITY	4TH PRIORITY

Fig. 4: Performance Values of Teams w.r.t. P1

3.5 Modelling the assignment and realising the optimal project assignment:

The company wishes to maximise its Profit Margin and Budget foreach project along with enhancing its Team Profiles. Thus, we have two criteria to maximize: Team Performances and Cost. On the other hand, the company wishes to reduce the time it takes to complete a project with the ulterior motive of completing more projects in the same time frame. It also wishes to minimize the risks and the complexities it faces while taking charge of these projects. Hence, we have two criteria to be minimized: The Time criterion and the Others criterion. Thus, our mathematical linear program is a Bi-Objective Linear Program. Another point that the company wishes to keep in mind is that every team should be assigned at-least one project but not more than Four projects.

Sets and Parameters:

I=set of projects = { 1, 2, 3,....10}

J=set of teams = { 1, 2, 3, 4, 5 }

G=set of main criteria={P, T, C, O}

P_{ij} = Performance Value of Team Profile when ith project is assigned to jth team.

C_{ij} = Performance Value of Cost when ith project is assigned to jthteam.

T_{ij} = Performance Value of Time when ith project is assigned to jthteam.

O_{ij} = Performance Value of Others when ith project is assigned to jthteam.

W_g =weight of the gth criteria

Decision Variable

$$X_{ij} = \begin{cases} 1, & \text{if } i^{\text{th}} \text{ project is assigned to } j^{\text{th}} \text{ team} \\ 0, & \text{Otherwise} \end{cases}$$

The linear programming model obtained for the given problem is:

$$\text{Max } z = (\sum_{j=1}^5 \sum_{i=1}^{10} P_{ij} X_{ij}) w_P + (\sum_{j=1}^5 \sum_{i=1}^{10} C_{ij} X_{ij}) w_C$$

$$\text{Min } z = (\sum_{j=1}^5 \sum_{i=1}^{10} O_{ij} X_{ij}) w_O + (\sum_{j=1}^5 \sum_{i=1}^{10} T_{ij} X_{ij}) w_T$$

Subject to constraints;

- $\sum_{j=1}^5 X_{ij} = 1$, for all $i=\{1,2,3,4,....10\}$
- $1 \leq \sum_{i=1}^{10} X_{ij} \leq 4$, for all $j=\{1,2,...., 5\}$
- $X_{ij} \in \{0,1\}$

4. DATA

The Data has been obtained from the priority values for each project corresponding to each team from the Performance Value Analysis done in the ANP software shown in Table 2. It consists Ten columns and Five rows each. The columns represent each of the Ten projects considered in the problem and the rows in each of the tables corresponds to each team i.e.; Team 1, Team 2, Team 3, Team 4 and Team5 respectively. In Table 2, P_i denotes the project number (where $i=1, 2, 3,....10$) and T_k denotes the team number (where $k=1, 2, 3, 4, 5$)

TABLE 2: Performance Value Analysis

P_i T_k	P1	P 2	P3	P4	P5	P6	P7	P8	P9	P10
PRIORITY VALUES WRT TEAM PROFILE CRITERION										
T1	0.31642	0.28931	0.34513	0.28882	0.26195	0.27711	0.22828	0.35152	0.37950	0.26414
T2	0.273916	0.296273	0.253229	0.356216	0.281331	0.231862	0.228627	0.269071	0.228627	0.264144
T3	0.190366	0.189379	0.185342	0.181717	0.270756	0.104342	0.354398	0.199124	0.203178	0.195074
T4	0.099862	0.11977	0.081804	0.097391	0.098635	0.104342	0.115401	0.098483	0.115401	0.299781
T5	0.11943	0.105266	0.134489	0.075847	0.087324	0.092376	0.073289	0.081797	0.073289	0.070028
PRIORITY VALUES WITH RESPECT TO COST CRITERION										
T1	0.381129	0.263796	0.255232	0.276385	0.170049	0.192338	0.274964	0.181855	0.279026	0.212948
T2	0.200447	0.345955	0.255232	0.371262	0.302982	0.299778	0.293416	0.107032	0.114809	0.125332
T3	0.184234	0.156455	0.187887	0.153391	0.306401	0.280926	0.209478	0.327867	0.19507	0.212948
T4	0.088561	0.14233	0.150825	0.099481	0.110284	0.130103	0.127342	0.249597	0.267734	0.292272
T5	0.145629	0.091464	0.150825	0.099481	0.110284	0.096856	0.094801	0.133649	0.143369	0.1565
PRIORITY VALUES WITH RESPECT TO TIME CRITERION										
T1	0.404196	0.348633	0.193686	0.426585	0.426585	0.426585	0.426585	0.426585	0.426585	0.426585
T2	0.253521	0.349633	0.443429	0.253032	0.253032	0.253032	0.253032	0.253032	0.253032	0.253032
T3	0.154442	0.148192	0.193686	0.146141	0.146141	0.146141	0.146141	0.146141	0.146141	0.146141
T4	0.093921	0.108551	0.0846	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121
T5	0.093921	0.045991	0.0846	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121
PRIORITY VALUES WITH RESPECT TO OTHERS CRITERION										
T1	0.400848	0.4153	0.236023	0.29464	0.278845	0.304152	0.336055	0.211376	0.298768	0.20744
T2	0.19397	0.205577	0.38398	0.321283	0.217025	0.331656	0.261562	0.279985	0.279985	0.274771
T3	0.19397	0.162359	0.196065	0.172677	0.304061	0.178251	0.196949	0.298768	0.211376	0.154618
T4	0.093143	0.120314	0.091966	0.132445	0.125345	0.104436	0.115391	0.119795	0.119795	0.274771
T5	0.118069	0.096451	0.091966	0.078956	0.074723	0.081505	0.090054	0.090076	0.090076	0.088399

5. RESULTS AND DISCUSSION:

We solve the Bi-objective problem obtained in section 3.5 by the epsilon constraint method which helpsto solve the multi-objective linear programming problems. The model is coded and solved in LINGO 11.

Solving the Minimization problem first we get the following solution in the software,

!Global optimal solution found.
Objective value: 0.4012607
Objective bound: 0.4012607
Infeasibilities: 0.000000
Extended solver steps: 0
Total solver iterations: 16

Using the minimization objective as an additional constraint and solving the maximization problem, we get the following solution

!Global optimal solution found.
Objective value: 1.262002
Objective bound: 1.262002
Infeasibilities: 0.000000
Extended solver steps: 0
Total solver iterations: 52

6. CONCLUSION

On solving the given Mathematical assignment model developed for this problem, the final result is obtained given below,

$$X_{11}=1$$

$$X_{62}$$

All other decision variables are zero.

$$X_{72}=1$$

$$X_{24}=1$$

$$X_{34}=1$$

$$X_{85}=1$$

$$X_{43}=1$$

$$X_{93}=1$$

$$X_{55}=1$$

$$X_{10,1}=1$$

Hence, the optimal assignment satisfying the constraints is obtained as shown in table no. 3:

TABLE 3. Optimal Assignment of Projects to Teams

Teams	1	2	3	4	5
Project Assigned	1 and 10	6 and 7	4 and 9	2 and 3	5 and 8

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An Empirical Investigation of Small Manufacturers for Operational Reliability

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Abstract: Reliability of a supply chain depends on the reliability of its various components. To be responsive and cost effective. It is very essential to estimate the reliability of the whole chain as well as the individual player. This is very essential to conduct suitable reliability tests and modify them as per the dynamic environment. For this work a statistical tests are conducted with the help of data collection for various elements. On the basis of that the overall reliability is also estimated. Then various suggestions based on investigation are proposed to improve the reliability and acceptability of the small suppliers in supply chain.

Keywords: Reliability, Uncertainty, Risk Assessment, Supply Chain Management

1. INTRODUCTION

Supply chain management Is the key of thought in today's story with basic purpose to integrate all elements of supply chain to improve the supply chain value increase. Supply chain is play important role globally and stimulates the dangerous opportunities in India also. The global manufacture are reduce the cost and increased their quality continuously. Therefore the cut throat competition they are India. Large scale of manufacturers are taking full advantages in India. The changing global story but despite many policy measures for the part of decades, the significant not shown by small scale units. Its improvement to share the global market with large manufactures. This department is very small, and technologically back ward. In which, some of the large problems faced by the factor are access to timely and adequate credit, technological obsolescence, infrastructural. Large scale manufacturers having a cyclonic market. And multiplicity of rules and regulations. Because Condition of this situation the sector of Indian manufacturing could not melt the global expectation and absent the opportunities which really knocking our doors. The small scale industries having special things is that, it highly fragmented and having a pyramidal structure. It means that establishment size is minimize number of unit goes up. The maximum competition occurs by this structure at small and mini sectors. This competition minimum the profit margins, which makes the worst condition. The player of Indian or global in small scale units is supply uncertainty compels the company to keep the high volume of safety inventories. It is very hardly accepted by any big player. In supply chain manufacturing, the small suppliers are considered as the uncertainty generators. Reason is that competency removed from the supply chain. The support of government is proper for small scale industries but it is not enough. In this area, the medium and large manufactures and academia should

study for resolve their problems. We can say that this sector can also become an effective and skillful player of supply chain and exploits the advantages of globalization and liberalization.

On the basis of study conducted for a small scale manufacturing unit manufactures auto parts of this paper. This paper is situating at Mathura. In which, the study one of supply uncertainty and analyzed as a supplier selection metrics and over all supply chain performance.

Benski and Cabau [1] emphasis to use the field data to estimate the Reliability and analyze the supply chain performance through it as it gives more realistic results.

1.1. Initial Investigations

The unit basically manufactures various small auto parts for bigger suppliers situated at Noida. From last four years this unit has been facing a tremendous problems related to the quality of products, scheduling, lead time, frequent failures and breakdowns. Because of the above mention reasons and increasing competition this unit lost almost all of its orders and out of the market.

Following points are come out after the initial phase of discussions with the proprietor and senior persons of the unit.

- Initially the unit was doing well with expertise in machining products.
- Later on situation become tough because of increasing competition.
- Company could not manage to manufacture and deliver the products timely.
- Quality and costing were also vulnerable issues.

It is decided to conduct Reliability Tests with past failure data of various machines and then analyze its effect on the supply chain. Manufacturing Unit under consideration is having various machines like Milling machines, lathe machines, Drilling machines, furnaces etc. The layout of the unit is process type to support manufacturing of the variety to products of small batch sizes. Apart this it also have small product lines dedicated to large order size items. For the present work one of such product line is considered three machines are considered in a series combination.

2. MATHEMATICAL ANALYSIS

Rajpal et al[2] developed an artificial neural network for simple systems. But it could not work with actual complex systems. For this Statistical model based on Weibull distribution is developed. Validity of this model has been done with goodness of fit tests conducted.

2.1. Steps of the Analysis

- Empirical Reliability is estimated with the help of failure data available using Rank Increment method. Initial estimation of Weibull parameters i.e. shape parameter and scale parameter are done using least square methods and normal equations.
- Statistical tests are conducted to determine the Maximum Likelihood Estimator (MLE) of the parameters. Mann's Goodness of fit test is conducted to verify the assumption that failure data is following two parameter Weibull distribution or not.
- Reliability and MTBF (Mean Time Between Failure) are estimated as per weibull Distribution.
- Over all Reliability of the system is estimated.
- Supply lead time and lead time variability is analyzed with the status of reliability. Relation between buyer's safety inventory and supply lead time and supply time variability is analyzed. Further the implications are studied for a supplier to be selected in a supply chain and remain the part of it for a longer time.

2.2. Rank Increment Method.

This method is used initially to drive the cumulative failure and then empirical reliability with or with out censored data. Since a censored unit has some probability of failure before or after the next failure, it will have influence the rank of the subsequent failure.

Rank Increment= [(n+1)–rank of previous failed]/[(n+1)–All the previous failed or withdrawn]

----- (1)

Here n = total number of units put on test

Now the adjusted rank is

$$i_t = i_{t-1} + \text{rank increment}$$

i_t = Rank of failures

i_{t-1} = Rank of previous failure

The empirical reliability function can be given as

$$\text{Reliability} = 1 - [(i_t - 0.3) / (n + 0.4)] \quad \text{-----} \quad (2)$$

The reliability of any unit can be derived at different failure times in a tabular form.

2.3. Weibull MLE

The MLE Of two parameter Weibull distribution can be calculated numerically. For shape parameter β the equation is

$$[\Sigma (t_i^\beta \ln t_i + (n-r) t_s^\beta \ln t_s) / \Sigma (t_i^\beta + (n-r) t_s^\beta)] - (1/\beta) - (1/r) \Sigma \ln t_i = 0 \quad \text{-----} \quad (3)$$

MLE estimate of Scale Parameter

$$\theta = \{1/r[\Sigma t_i^\beta + (n-r) t_s^\beta]\}^{1/\beta} \quad \text{-----} \quad (4)$$

Here r = number of failures, n = number of items on testing t_i = failure time of i th item, $t_s = 1$ for complete data

For complete failure $r = n$

2.4. Mann's Test for Weibull Distribution

This is a special test for Weibull distribution developed by Mann, Schafer and Singpurwalla (1974). Ebling [1] The hypothesis is given as

H_0 : the failure times come from Weibull distribution.

H_1 : the failure times did not come from the Weibull distribution.

The test statistic is

$$M = K_1 \Sigma [(\ln t_{i+1} - \ln t_i) / M_i] / K_2 \Sigma [(\ln t_{i+1} - \ln t_i) / M_i] \quad \text{-----} \quad (5)$$

$$\text{Where } K_1 = [r/2] \quad K_2 = [(r-1)/2] \quad \text{--} \quad (6)$$

$$M_i = Z_{i+1} - Z_i \quad \text{-----} \quad (7)$$

$$Z_i = \ln[-\ln(1 - (i-1)/(n+0.25))] \quad \text{-----} \quad (8)$$

Here $[r/2]$ is the integer part of the number $r/2$.

M_i is an approximation.

if $M > F_{\text{crit}}$ the hypothesis H_1 is accepted otherwise H_0 is accepted.

The values of F_{crit} can be obtained from the tables of F distribution where the degree of freedom for numerator be 2 K_2 and number of degree of freedom for denominator be 2 K_1 .

2.5. Impact of Supply Lead Time Uncertainty on Safety inventory

Uncertainty in supply lead time affects the performance of the supply chain drastically. This forced the buyer to stock the safety inventory as per the supply time uncertainty, the situation becomes worst with high variability in supply lead time. In actual cases buyers never tolerate these types of suppliers as lot of money blocked in safety inventories. As the result of this these supplier loses their stake in the supply chain.

2.5.1. Cycle Service Level

It is very important metrics to judge the quality of supplier. CSL is the probability that of not having a stock out in replenishment cycle. It is the fraction of replenishment cycles that ends with all the customer demand met. It is measured over a specified numbers of replenishment cycles [9].

2.5.2. Expected Safety Inventory

To understand this problem an inventory model is considered to predict the safety inventory under supply lead time uncertainty. Ref[9]

Let the Avg demand per period = D
 Std Deviation in demand per period = σ_D
 Avg lead time for supply replenishment = L
 Std. deviation in supply lead time = S_L
 Considering both supply and demand lead time uncertain
 Demand during lead time can be estimated as $D_L = D.L$ --
 ----- (9)

$$\text{Std Deviation } \sigma_L = (L \cdot \sigma_D^2 + D^2 \cdot S_L^2)^{0.5} \quad (10)$$

$$\text{Safety stock of the inventory } SI = ES^{-1}(\text{CSL}) \cdot \sigma_L \quad (11)$$

(Here CSL is cycle Service Level and ES^{-1} is an excel function to get the Inverse of the standard normal cumulative distribution)

3. DATA ANALYSIS

3.1 Reliability Analysis

3.1.1 Weibull distribution MLE and Mann's Test Statistic

(For Lathe Machine)

Solving by iterations with the help of Excel data sheet, the value of MLE $\beta = 1.519$

Now putting this value of β in equation

$$\theta = (18635.3)^{.6583} = 533.87 \text{ Hrs}$$

(Similarly these parameters can be calculated for other machines.)

After finding MLE of the Distribution parameters a goodness of fit test is conducted which is basically a statistical test.

Here Mann's test is considered to test the Weibull failure distribution.

Test statistics are $M = K_1 \sum [(\ln t_{i+1} - \ln t_i) / M_i] / K_2 \sum [(\ln t_{i+1} - \ln t_i) / M_i]$

Where $K_1 = [r/2]$

$K_2 = [(r-1)/2]$

$M_i = Z_{i-1} - Z_i$

$Z_i = \ln [-\ln(1 - (i-1)/(n+0.25))]$

Here $[r/2]$ is the integer part of the number $r/2$.

If $M > F_{\text{crit}}$ the H_1 is accepted.

Number of test (n) = 11

Number of failure (r) = 11 $K_1 = 5, K_2 = 5$

So the Mann's test Statistic is

$$M = 5 * 3.45531 / 3.91143 * 5 = 0.8833$$

Number of degree of freedom for numerator

$$2 * K_2 = 2 * 5 = 10$$

Number of degree of freedom for denominator

$$2 * K_1 = 2 * 5 = 10$$

Now the value of F_{crit} may be obtained from F- distribution
 $F_{\text{crit}} = 2.97$ (from F- distribution table)

$$M < F_{\text{crit}}$$

Thus Hypothesis H_0 is accepted which says that the failure times come from Weibull distribution. (Similarly MLE estimation and Mann's Test are conducted for all the machines.)

3.1.2. Over All Reliability of System.

The over all reliability of the system is calculated as per the series combination of various machines. $R_{\text{sys}}(t) = R_L(t) * R_M(t) * R_{\text{HB}}(t) = 0.8343 * 0.9742 * 0.9288 = 0.748$

3.2. Cycle Service Level

From records it was found that from last two years unit send twenty two deliveries to a particular company. Out of that about 12 were found to be in the quoted supply time rest were late. With this information CSL can be estimated as $\text{CSL} = 12 / 22 = 0.55 = 55\%$

With such a small value of service level safety stock could be very high it is estimated later on.

3.2.1 Standard Deviation in Supply Lead Time

From records various supply lead times are takes as (in weeks)

21, 30, 21, 19, 18, 14, 11, 36, 39, 23, 11, 20, 19, 19, 22, 17, 16, 19, 23, 28, 27, 15

With this data avg value of supply lead time is 21.27 weeks
And Std. Deviation in supply lead time $S_L = 7.15$ weeks

3.2.2 Effect of CSL and Standard Deviation of Supply Lead Time on Safety Inventory

TABLE-1

Avg demand per period D(assumed)	Avg Lead Time	Std Deviation in Demand per period	Std Deviation in Supply Lead Time	Safety stock during lead time D.L	Std Deviation in demand during lead time $\sigma_L = (L \cdot \sigma_D^2 + D^2 \cdot S_L^2)^{0.5}$	Extra Safety stock For supply time deviation $SI = ES^{-1}(CSL) \cdot \sigma_L$
1000	21.3	150	7.15	21250	7133	900

In above table it is shown buyer has to make a very large safety inventory due to large value of supply lead time moreover it is further required to keep extra inventory for deviation in supply time.

4. SUGGESTIONS TO IMPROVE ACCEPTIBILITY OF SMALL SUPPLIER IN SUPPLY CHAIN

- Proper preventive maintenance plans are required as the machines are old and lying in wear out zone. This will help to reduce supply lead time and improve quality of product.
- Increasing number of machines (redundancy) can also improve the reliability and can reduce the supply lead time.
- A comprehensive RAM Analysis followed by FMECA Analysis can help to identify and mitigate the various causes of failures and poor performance.
- A proper training to the employer and employee can induce competency up to some extent.

5. CONCLUSION

Statistical investigation of performance data indicates the various critical issues of the system and its effects on the performance of the supply chain. Because of frequent

failures, break downs and obsolesces of machines the operation reliability of the system is very low about 0.74 which can be further lowered if all machines and equipment will be considered. Due to lower operational reliability company could not supply the items in shorter supply time which ends up with a high level of safety inventory for buyer and the situation becomes worst when it could not meet the supply lead time which it quotes to its buyer as it forced the buyer to keep extra safety inventory to cope with supply time deviation. But the buyer never wants to keep its safety inventory level high as it reduces its profit margin and over all supply chain profitability. Due to above reasons these suppliers struggle and ultimately moved out from the supply chain. If small supplier could get sufficient support from the bigger players and academia it could survive and effectively participate in supply chains to exploit the globalization.

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Integrated Approach for Job Scheduling in a Production System

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Abstract: When a large number of jobs and machines are taken into consideration, efficiency in job shop scheduling plays a vital role. As the number of jobs & machines increase, the job shop scheduling problems approaches to a higher difficulty level. Many heuristic methods are devised that produce solutions with near optimal solution. This work deals with the job shop sequence using an algorithm aimed at creating a simulated model. The input parameters are the demand, work in progress inventory. The current paper emphasis on optimization of a production line with an objective to reduce the makespan and increase the utilization of machine.

Keyword: Jobscheduling, Makespan, MachineUtilization, Simulation, Optimization.

1. INTRODUCTION

In a manufacturing line, makespan stands for the time of beginning of processing of the first job in the lot to the last job is completed. By improving makespan one can achieve higher production rate, and be able to meet the demand as per or before the dates. Researchers are constantly aiming to reduce the makespan by using different approaches.

The flow shop scheduling model was first developed by Johnson, 1954. Johnson developed an exact algorithm to minimize the makespan for 2- machines flow shop scheduling problems. The flow shop scheduling problem has proved to be NP-hard. Due to the complexity of the problem, it is difficult to develop exact methods to solve this problem. Hence, researchers proposed different heuristics and meta-heuristics to solve the flow shop scheduling problems. The important heuristics were developed by Rajendran and Chaudhri, 1990 and also proposed to solve the flow shop scheduling problems. Akhshabi et al., 2012 proposed a parallel genetic algorithm to minimize the makespan of flow shop scheduling problems. Vince Caraffa, 2001 uses considering the problem of minimizing the makespan of flowshop operating without buffers (intermediate storage) and develops a genetic algorithmic approach to solve large size restricted slowdown flowshop problems of which blocking flowshop problems as a special case.

Review of literature provides motivation to develop and demonstrate a model for optimization using simulated based approach for job shop planning and job scheduling for a multi-component machine. This paper is organized as follows. Section 2 presents the industrial problem description. A section 3 gives detail of the approach and formulation. Section 4 gives the results and graphs. Section

5 concludes the paper and identifies the future scope of work.

2. INDUSTRIAL PROBLEM DESCRIPTIONS

Work done in this paper is based on working of a manufacturing industry AVTEC LTD. Pithampur, M.P, which is a manufacturer of power train and precision-engineered products. Production line producing multiple components is studied where 3 different components are processed on a single machine. The sequence of components to be processed directly affects the make span and make span is related to the production rate and higher cost to the company as well. Also, some what if scenarios are also considered like what if demand of any product increases suddenly then what should be the sequence of components to be processed? Similarly, sequence of components will also lead to change in total machine utilization. Machine utilization is an important factor from the production point of view.

AVTEC LTD has been divided in three sections namely engine plant, transmission and assembly line. The research is conducted in the engine plant specifically on a camshaft line which has 11 machines, each having different operation and cycle time. The camshaft line is chosen because most of the machines are mature and lot of data is available there. The components are manufacture in single lot or batch to eliminate the time lost due to setup change. On the very first machine, 3 different components are processed out of which 1 component is sent to different line for further operations and remaining are forwarded into the same line. First machine is a batch machine so the sequence of operations on components is followed by the operation on the first machine. The process of operation on a component is enlisted in table 4 in a reference. In order to meet the

consumer demand Three shifts are run: A and B are staffed with 8 operators, with the night shift C, is staffed with 2 operators. The bulk of the production is completed by shifts A and B, with C producing a small quantity and being deployed on machines that were disrupted in the other shifts. Available time for a month is 31200min. Along with improper scheduling, production is also affected by the unavailability of raw material by suppliers' end. There are two suppliers for a camshaft line, effect of one supplier is neglected because of its large lead time and data related to lead time is described in table 3. This leads to concentrate on finding proper sequence for optimizing the makespan period and machine utilization.

3. APPROACH

A model of production line is prepared on the simulation software. This model represents the production line considered for this work. All the data are fed to the model like cycle time, machine failure behaviour, inventory (work in process, finished goods), demands, etc. are collected from manufacturing industry. Some basic logics of coding like IF- ELSE logic and some pre-defined keywords existing in software are used. Also total Work in progress (WIP) inventory were constrained as:-

For product 1
 $WIP \leq 230$

For Product 2
 $WIP \leq 60$

All the variable data can be fed through MS-Excel, and result can be obtained in any form either MS excel or other software.

Each optimization problem should have an objective function that has to be either minimized or maximized in order to obtain a certain solution. In this case, the objective function is the value of makespan and the total machine utilization. The span value can be defined as follows

MAKESPAN

$$F(x) = \sum_{i=1}^n CT_i + \sum_{i=1}^n WT_i$$

Where 'CT' represents cycle time,
 'N' represents total number of parts
 'WT' represents time loss due to loading – unloading of parts.

MACHINE UTILIZATION

Machine Utilization can be calculated as –

$$G(x) = 1 - \frac{\sum DT}{\text{Available time}}$$

Where 'DT' denotes downtime

From the above equation makespan and utilization are calculated for different scenarios of sequence to get the optimized result.

4. RESULTS

Various sets of data regarding machine failure behaviour, supplier's lead time, cycle time, demand pattern of different components from past and for many more parameters were obtained. After collecting this information, a detailed analysis is carried out to find some kind of pattern. According to data analysis, machine failure pattern was following Weibull distribution.

And demand variation is shown below: -

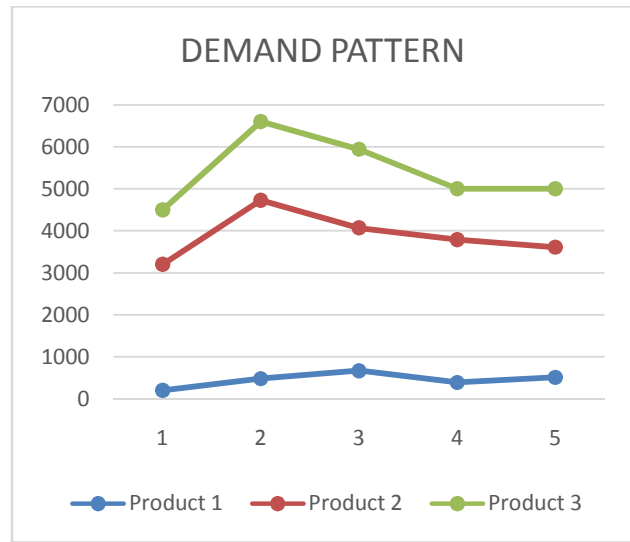


Fig. 1. Graph Showing Monthly Variation in Demand

Based on the model, Sequencing for the first machine is considered as major parameter for the above stated objective function. And the results found for different scenarios are depicted below

CASE 1

For regular demand i.e. based on the previous data available, makespan and machine utilization is obtained by varying the job sequence on machine, here 'P' is used to indicate the selected sequence. (Explained in Table1)

CASE 2

When demand of any one product gets double, and demand of other products remains same as previous.

CASE 3

When demands of all components are equal and are higher than the normal demand.

TABLE 1: Sequencing of jobs.

P	Job Sequence
1	Product 1, 2, 3
2	Product 1, 3, 2
3	Product 2, 3, 1
4	Product 2, 1, 3
5	Product 3, 2, 1
6	Product 3, 1, 2

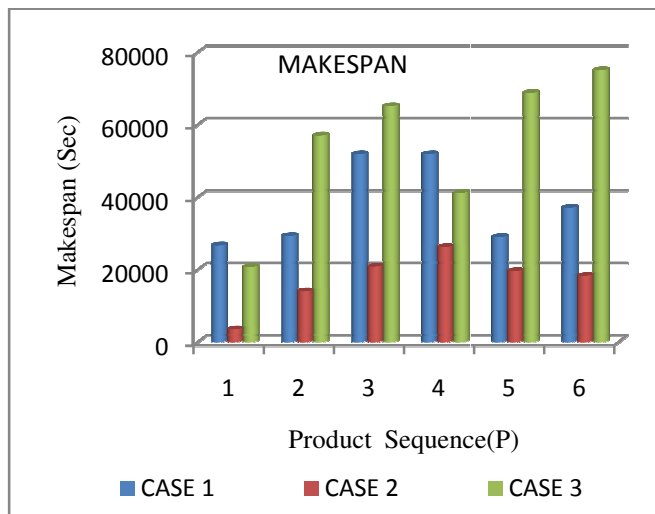


Fig. 2. Graph: MakespanVs Sequence

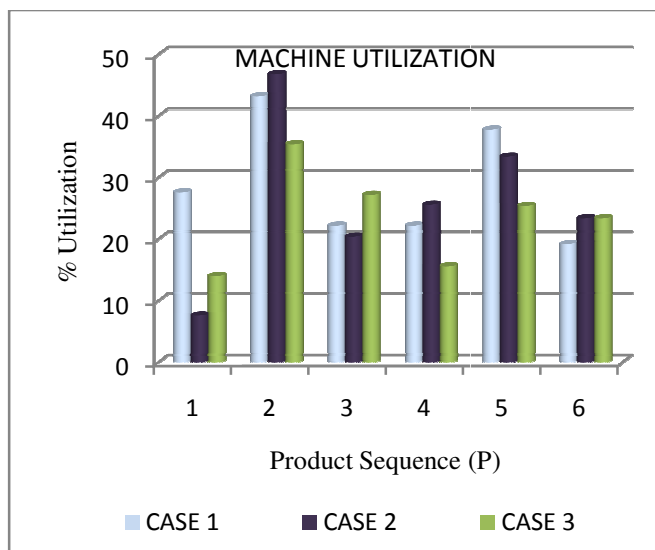


Fig. 3. Graph: Machine Utilization Vs Sequence

TABLE 2: Makespan and Utilization corresponding to the value of P, when value of η increased by 20%.

P	1	2	3	4	5	6
Makespan (Sec)	10145	54680	20792	23355	57225	60703
Machine Utilization (In %)	4.6	22.6	9.6	8.6	20.4	19.4

TABLE3: Supplier Lead Time

SUPPLIER	Pre-processing time	Post-processing time	Transit time
MAHLE	2 hours	2 hours	2 days
AKAR TOOLS	2 hours	2 hours	4 days

5. CONCLUSION

From the above Graphs and other simulations, one can conclude the following: -

- For any change in the demand, as in case2 and case 3 the sequence that yields minimum MAKESPAN is P=1 i.e. sequence should be Product 1, 2, 3. And for maximum MACHINE UTILIZATION, the sequence is P=2 i.e. Product 1, 3, 2.
- If the Mean Time to Repair is changed by increasing the value of η by 20%, then the sequence remains same and value of MAKESPAN decreases and MACHINE UTILIZATION increases, but on further changes in η value yields the same optimized value.

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TABLE 4: Process flow and characteristics of a camshaft

OP.NO	Operators assigned to m/c	Machine	Process Description	Breakdown and repair time distribution	Cycle time (min)
10	1st	FACING &CENTRING SPM	Facing and centring	Weibull (1.69, 177574) & Gamma (1.66, 99.6)	3.0
20	2nd	LT-20 Lathe.	Turning	Weibull (1.84, 148357.6) & Gamma (. 04, 247.15)	12.0
30	2nd	Durga SPM	Drilling and tapping	Weibull (1.62, 6380.22) & Gamma (. 95, 195)	5.0
40	3rd	G-18	Stop-end Grinding	Weibull (1.18, 175593.12) & Gamma (2.29, 74.93)	5.0
60	4th	FORTUNA	General Grinding	Weibull (1.84, 148357.6) & Gamma (. 04, 247.15)	5.6
70	5th	NTC	Cam-Grinding	Weibull (1.18, 175593.12) & Gamma (2.29, 74.93)	4.0
80	6th	COOPER –HOBGING MACHINE	Gear hobbing		13.5
90	6th	FOOTWORD SUPERFINISHING MACHINE	Super finishing		2.0
100	4th	RDM	Drilling		5.2
120	7th	PHOSPHATING	Cam shaft phosphating	Weibull (1.77, 208173.10) & Weibull (1.68, 115.3)	8.9
130	8th	Ams	Keyway Milling		4.0

Computerised Maintenance Management Systems: A Critical Literature Review

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Abstract: Computerized Maintenance Management Systems (CMMS), also known as Enterprise Asset Management (EAM) is an essential operational and management tool for managing asset preservation, ensuring that production systems operate as required thereby minimizing downtime. The Purpose of a CMMS is to manage, capture, track inspection, maintenance and repair activities of an organization. It provides a scheduling facility for maintenance for planned preventive work on maintainable assets. CMMS can eliminate manual data entry, incorporate alerts and shift focus from unnecessary administrative tasks to performing maintenance activities. These systems not only allow the maintenance groups to save time with calibrations and record keeping, but also check on field device performance online. As an added benefit system such as these are allowing maintenance groups to move from a reactive to predictive approach in their daily activities. CMMS helps in improving inventory control, work order generation, asset management, safety, regulatory compliance, real-time reporting, lower overhead, reducing the amount of time when machines are not in use, killing downtime in effect. CMMS solutions can be found in almost every industry because they bring to the table substantial organization, maintenance planning, control of maintenance and cost savings. CMMS users include facility and maintenance management, asset planners as well as maintenance staff.

Keywords: CMMS, EAM, JMAR, RCM, GIS.

1. INTRODUCTION

1.1 MAINTENANCE

Actions necessary for retaining or restoring a piece of equipment, machine, or system to the specified operable condition to achieve its maximum useful life. Maintenance comprises of concepts for the optimization of equipment, procedures, and departmental budgets to achieve better maintainability, reliability and availability of equipment. Maintenance involves keeping the workplace, its structures, equipment, machines, furniture and facilities in good repair and operating efficiently and safely. It includes many tasks like repairing, replacing, servicing, inspecting and testing. The term could also be used in relation to the importance of keeping your staff safe, fit and healthy. Maintenance can also be classified as Planned Maintenance (Corrective, Predictive, Preventive) and Unplanned Maintenance.

1.2 CMMS

CMMS is a computerized system designed to enhance efficiency and effectiveness of maintenance activities typical features include planning, scheduling and monitoring of work orders and maintenance needs. It maintains a computer database of information about maintenance operations. It helps for quickly and efficiently deciding, planning and organizing various jobs for effective maintenance. Before applying CMMS, various factors

should be taken into considerations like reduced cost, better organizational methods, reduced paper work and improved communications. CMMS can be applied in various areas like Manufacturing, Federal, State and Local governments, Property Management, Hotels and Resorts, Energy Plants, Oil, Gas and Mining, Hospitals and Clinics, Schools and Universities

2. LITERATURE REVIEW

2.1 Application of Modern Computerized Maintenance System

This paper brings the attention to the considerable effects of computerized maintenance systems upon the overall production economies; the implementation of maintenance systems potentially leads to the reduction of production costs by 10-15% and increase of utilization of production capacities in the range of 15-30%. Such results are rather difficult to achieve using even the most sophisticated production control and planning/ scheduling algorithms developed with great effort.

A case study of the development and implementation of the Czechoslovak UNDP/UNIDO project "Application of Modern Computerized Maintenance System" is given, Co-ordination of production and maintenance plans by the use of computerized data base, including spare parts manufacture and inventory control, further contributes to the overall maintenance and production economies. This

paper describes a computerized maintenance system project that has proven these results in the field of metallurgical production in Czechoslovakia. The implementation of such systems in other countries has shown similar experience. (Krouzek 1987)

2.2 Database Technology and the GIS Field Program

This paper discussed the database technology and the GIS field program to maximise the life of wood poles that supports the electrical transmission lines. In database technology, automated mapping process is time consuming and manpower intensive process that often yields less than satisfactory results, so the global positioning system is a reliable tool for positioning the wood poles. GPS combined with quality attribute collection in the field, provides a product that will sustain future mobile computing application. New technology makes data gathering in the field lower in cost and more accurate. More accurate data leads to good management and decision making of field and attachment inventory. (Bingel et al. 1998)

2.3 CMMS as Database / Calibrator System

The author categorizes CMMS in two types-database/calibrator system, database/calibrator/online system. Both systems use a computer, a database and a handheld calibrator. The main difference is that the second one consists of smart field devices (that are equipped with microprocessor), a communication protocol and software which can reside in a personal computer. The system represents the information and calculation in a consistent format. In this fashion maintenance personnel can be automatically and instantly notified of a device needing maintenance. (Medlin. 1999)

2.4 Challenges and Implementation Process

After successful implementation of CMMS in Chelan County PUD, author explains challenges and implementation process. CMMS provide a large database and the analysis tools to improvements based on recorded history. Requirement for implementing CMMS are: Training of workers, Collaboration of supervisors and managers with craftsmen and a dedicated and focused CMMS project team. These systems also provide users with one program that support a multitude of functions other than maintenance.(Blackmore 2001)

2.5 Development of JMAR

The author discusses on ongoing medical informatics and business process reengineering research project. The paper focuses on JMAR (Joint Medical Asset Repository) used by US military service. JMAR was originally envisioned to correct medical supply and drug distribution problems that occurred during operation desert storm. This paper discusses the history and development of JMAR from 1997

JMAR is a critical component of the joint vision 2020 plan is an aggressive and all-encompassing one, and it seems well be ahead of civilian efforts found in the literature to date.(Sloane et al. 2003)

2.6 CMMS in Power Systems

For power systems there are usually millions of maintenances intensive equipment's whose reliability is important for power system security and safety. Inthe given paper author has introducedCMMS and recommended to deal with this problem. The paper also discusses the general information-processing model proposed by Hassanain in order to implement the CMMS successfully. This general model consists office sequential management processes:(1) Identify Asset, (2) Identify Performance Requirements, (3) Assess Performance, (4) Plan Maintenance, (5) Manage Maintenance Operations. Successful CMMS is expected to help electric utilities manage resources effectively andimprove utilities' efficiency considerably.(Zbihong et al.2005)

2.7CMMS for Military and Medical Sector Uses

The author designed and implemented a CMMS to be used at the Chilean Naval Hospital Biomedical Engineering Department. It is designed to meet the specific needs of this military facility and follows the Generic Clinical Engineering Maintenance Management System suggested by Association for the Advancement of Medical Instrumentation (AAMI). (Acevedo et al. 2005)

2.8CMMS Supported by GIS

In the developing country like Indonesia to reach a high reliability index is still very difficult. Yogyakarta province as a part of Indonesia, the electric power supply is managed by Yogyakarta electric power distribution region that serve more than 650, 000 customers and supported by more than 11, 000 power distribution transformers.The CMMS is developed on based of digitalizing distribution line networks, customers' connection, inventory of the assets, and man power.

This CMMS also supported by GIS in conjunction with the reduction of the time needed to restore the system during fault. The first stage is the development of the Geographical Information System application. The second stage that must be carried out is the integration between the application of the customer service, payment system and power failure services. The integration of these elements will make the system able for real-time monitoring working. (Tumiran 2008)

2.9 CMMIS for a Tyre Manufacturing Process Industry

The author developed CMMIS for a tyre manufacturing process industry. He described drawbacks and advantages of CMMIS. Modules used by author are equipment menu,

work order process menu, preventive maintenance menu and spare part details. These modules and sub modules provide all the information that a maintenance manager need and also provide a good data base for day to day decision making, in long term planning, reduction in downtime, reduction in maintenance cost and inventory cost and increased productivity, etc.(Ramachandra 2012)

2.10 CMMS For Medical Devices by Prioritising it Bases on its Effect

The author designed a CMMS for medical devices CMMS for medical devices in Royal Medical Services. The effective maintenance management of medical technology influences the quality of care delivered and the profitability of healthcare facilities. The existing system for maintenance was studied and a need for change was observed. Traditionally the maintenance was carried out on 'First come first serve basis.' The suggestion was made to prioritise the maintenance of devices based on their effects on the patients due to their failure. The five steps of maintenance (Notification, Assignment, Job-in-progress, Closure and Reporting) were integrated into the existing system.(Fouad et al. 2012)

2.11 Development of CMMS for Storage and Accessible by LAN

The author discussed the design, development, and Implementation of maintenance software for RDCIS, SAIL. The civil and electrical maintenance activities were outsourced to contract parties, that were selected through open Tender enquiry basis. The existing software had a limited scope, running on a standalone personal computer supporting only one application user. It did not have the provision to keep the history of previous year records. There were no separate soft wares for Civil and Electrical maintenance. The Implemented CMMS software: The project comprised of database design, application design and development of software for storage and retrieval of the scanned documents through user friendly interfaces, The CMMS software was implemented on web based 3-tier technology. The application can be accessed on LAN using the clients like Internet Explorer, Firefox, Chrome, etc. by giving the URL address for CMMS, the middle tier being Oracle application server and the Backend as Oracle database (record keeping). The author implemented the software comprising of five basic modules separating the civil and electrical maintenance for RDCIS Lab complex and SAIL Township and a Complaint lodging system.(Selvi et al. 2013)

2.12 Reliability Centred Maintenance in Gas Company

The author described the development and implementation of CMMS for National Iranian Gas Company. Maintenance strategy used for CMMS is Reliability centred maintenance(RCM). CMMS must be designed for

balancing the maintenance activities. CMMS should minimise the frequency of reactive maintenance as much as possible. For decision making about the priorities for through investigation, the work orders must go through a comparison process. CMMS must be launched from the beginning of the equipment life cycle. The final target of CMMS is identifying the essential events, items and work orders in terms of unit availability, reliability, quality control and maintenance cost, processing in a systematic way. It is suggested to do the survey about effectiveness of this model on plant life cycle.(Beni et al. 2014)

2.13 Reasons behind the Low Success Rate in Implementation of CMMS

The business in large industries greatly depends upon management of maintenance and has a significant impact on profits. Managing this process effectively without computer-based support is almost impossible. It is very common that there is a low success rate among even large organizations worldwide in implementing an effective CMMS to support improved reliability and performance. This paper focuses on understanding the reasons behind the low success rate in implementation of CMMS (6 key reasons) using "Iceberg Model". Author discusses the essential elements that must be included to ensure a disciplined and well-resourced program that can deliver success.(Wienker et al. 2015)

2.14 Multi-Attribute Decision-Making Methodology

He explained need for Computerized Maintenance Management System's decision analysis capability to achieve world class status in maintenance management. Investigations indicate that decision analysis capability is often missing in existing CMMSs and collected data in the systems are not completely utilized. This paper aims to assess and select the most efficient maintenance policies (like BM, TPM, CBM, SLU, DOM, RBM, TBM etc.) to add value to collected data. The analysis has been executed in Case study for manufacturing site in Sweden, to provide new CMMS by adopting a multi-attribute decision-making methodology, namely DMG (Decision making grid), TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) and K-means clustering. (Rastegari et al. 2016)

2.15 Identification of Requirements and Various New Features

He discussed the Requirements specification of a CMMS for changeable, agile, reconfigurable and Virtual Production. He aims to develop a CMMS involving the identification of requirements and the specifications of the system, are described in detail, showing the approach that was followed and reflecting about its effectiveness and efficiency. In this various proposed future improvement in CMMS are discussed with the weaknesses & limitations of

currently available systems. He introduced various new features in Maintenance planning, Maintenance scheduling, Performance measurement and improvement and Spare parts management. (Lopes et al. 2016)

2.16 CMMS for a National Thermal Power Plant

Author explained a general framework of CMMS for a National Thermal Power Plant. Currently, it is very difficult to maintain data in written form as it makes much difficult for retrieval of data. Using software for this purpose leads to efficient planning of maintenance aspects. CMMS leads to effective planning, controlling and scheduling of maintenance activities. Various modules such as Equipment, Work Order, Spare Parts, Tools & Tackles, Staff Details, Task Allotment and Safety Records are used. Author also gave general guidelines for creating a CMMS software. (Yadav et al. 2017)

3. CONCLUDING REMARKS AND FUTURE SCOPE

The paper includes various literature reviews of the research done in the field of CMMS for several Production and service sectors. CMMS being an essential operational and management tool for minimising downtime and reducing the overall production cost by increasing utilisation of production capacities. CMMS is part of Enterprise resource planning, is planning and controlling tool which aids the maintenance of enterprise by managing the operation/activities in the best possible way. It focuses on improving various maintenance policies like BM, TPM, CBM, SLU, DOM, RBM etc which helps in increasing the effectiveness of maintenance and focus on maintenance activities. The database maintained by the CMMS software offers easy record keeping, security (that makes tampering with the information practically impossible.) and aiding the maintenance staff by providing previous maintenance exercises. A Properly utilised CMMS can assure management of properly maintaining capital investments on costly plant equipment. CMMS process should be planned and shared. NO SURPRISES. Let the user know what you are doing and get their input. The fear factor is very high in activity based systems. No one has ever been “watched” this closely before.

CMMS can be applied in various areas like Manufacturing, Federal, State and Local governments, Property Management, Hotels and Resorts, Energy Plants, Oil, Gas and Mining, Hospitals and Clinics, Schools and Universities etc.

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Identification and Ranking of Factors Affecting Facility Location: A ‘Make in India’ Challenge

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Abstract: While deciding on Location Selection, the factors that enhance supply chain performance should be considered on prime basis. Presently, the Make in India initiative is aimed at luring investors all over the world to invest in our country. But looking back at a few issues like the Tata Singur plant, it is advisable that we have a proper framework ready for the investors that can guide them in locating facilities in India. Various dormant qualitative factors can surface at the time of finalization of facility location. Many a times, even after the location is finalized and facilities are built, these factors lead to closure of work in advanced stages that might cause huge losses to the business houses. This paper aims at assessing various existing and new qualitative and quantitative factors for location selection in developing countries and prioritizing them over each other.

Keywords: Facility Location, PESTLE Analysis, Supply Chain Performance Measures, Ranking by Paired Comparison.

1. INTRODUCTION

With businesses spreading all across globe, the countries worldwide are opening their boundaries inviting others for setting up plants. The major decisions in setting up businesses take place during the strategic phase. In this phase strategic decisions like type of facility, role of facility and location of facility have to be taken [M.T. Melo, 2009]. The facility location decision making has to be a long term strategic decision. The traditional methods of facility location are based on of minimizing the transportation costs based on suppliers and market locations [D. A. Schilling, 1993; Farahan, 2012]. Over the years, other quantitative factors and qualitative factors [Kalantari, 2013] have also been looked upon during Facility Location Selection. In recent research, qualitative factors have also been combined with quantitative factors [Dogan, 2014] for identifying a facility location.

As per the UN Industrial report, 2016, short term actions may produce quick and lucrative results, but the long-term consequences can be disastrous. Developed countries like United States, Germany and Japan have kept their positions in industrial competitiveness over the long term. These countries enjoy higher, and more sustainable, industrial performance. Such countries have strong industrial policies to back the industrial growth. India may rejoice that it is overtaking China as the world's fastest growing major economy, but the scenario looks more complicated than that. In one of the recent article in Hindustan Times, Five major challenges that loom for our Honorable PM's mission are funds, technology advancement, union issues, availability of skilled labour and overhaul of R & D in India [Narayan]. In one of the recent blog 'the benefits and challenges of manufacturing in India, Jessica Hoyt has identified power availability, cost and fragmentation of

transportation and logistics, labour productivity and intellectual property and protection and enforcement as the major challenges. The developing countries which usually have no firm policies have a lot of dynamic qualitative factors that may surface at the time of beginning of operations in the facility and are subjected to serious consequences that may include closure of the facility as seen in some of the recent cases. The paper aims at identifying such dormant qualitative factors, combining them with other qualitative and quantitative factors. Further, ranking of the factors is done to access their importance by using Ranking by Paired Comparison Method [Paul Newton, 2014].

2. PROBLEM ON HAND

With new initiatives, come challenges. The Make in India initiative of the Government will also have lot of challenges as India is still a Developing country. Over the past, we have seen that a lot of dormant qualitative factors like Political System [Michael, 1993], Maturity of political leadership, blind belief in leadership, Bureaucratic hurdles, Unstable neighborhood, Internal turbulence, internal threats [Sukanta, 2010], Roll of parallel economy [Thi, 2016], health impact [Yossi, 2013] that are vague in nature, predominantly seen in developing countries have not been considered in facility location decisions. Such dormant qualitative factors prevail come to surface when optimal location of the plant is already decided and can eventually turn out to be vital adversely affecting the decisions made and forcing relocation of plant. This has been evident from the past cases like Tata Singur plant shifting to Gujarat [Saibal Bishnu] and Nylon 66 plant moving out of Goa. Hence these factors have to be considered for facility location decisions.

3. METHODOLOGY

A gathering of individuals from industry and the scholarly world brought about distinguishing some dormant qualitative variables that can make issues subsequent to settling the location as found in many of the cases in later past through a group discussion. Political System existing in the nation has a noteworthy part to play in industrialization. This has been considered as one of the variables that can influence location choices. At whatever point a political framework emerges, leaders rise. The basic leadership towards modern development relies upon the matured initiatives taken by the leaders and hence the Maturity of political leadership has additionally been considered as one of the variables. In developing nations, in a large number of the individuals indiscriminately follow their leaders. Hence blind belief in leadership likewise happens to be one of the main considerations that can influence Location choices. Bureaucracy is one more major issue that was considered during brainstorming and many a times as an investor in business you may have a lot of bureaucratic hurdles during the initial phase. For any industry to progress, the area in which it is supposed to be located should have stable neighborhood. In recent past, some of the countries have been facing a lot of internal turbulence and have lots of internal threats, hence these factors have also been considered.

Parallel economy assumes a noteworthy part in numerous nations. In a few nations, whole business may keep running on parallel economy and it gravely influences the development. Role of Parallel economy is additionally enrolled as a likely factor to be looked after. All such factors can create issues even after finalizing the location as seen in some of the cases in recent past hence the authors feel that such factors should be considered along with the existing factors available in literature to develop the framework [Milind, 2017]. In a few nations like India Vastu-Shastra is picking up significance as of late [Edward J. Jaselski, 2015] and has likewise been considered as one of the factor influencing facility location. Supply chains can be disturbed during disasters having a huge financial and operational effect on firms [Trevor et al., 2005]. The location with high Disaster dangers will be never the principal decision for plant setup as the whole business can be damned. Henceforth Disaster Risks likewise must be considered during facility Location Selection. The Factors identified are organized as per PESTLE tool. As the factors are large in number, an alternative to Ranking by paired Comparison method has been devised and is used to rank the factors.

4. PESTLE

PESTLE stands for - Political, Economic, Sociological, Technological, Legal, and Environmental. The term PESTLE has been used regularly to help making decisions

and plan for future events looking at the Political, Economic, Sociological, Technological, Legal, and Environmental factors. An organization on its own cannot affect the factors, nor can these factors openly affect the profitability of an organization. But by understanding these environments, it is possible to take the advantage to maximize the opportunities and minimize the threats to the organization while taking facility location decisions. The various factors affecting Facility Location are classified in terms of Strategic and operational factors using PESTLE tool and are as shown in sub-sections [Milind, 2017]. The factors considered are further sub divided into Qualitative and Quantitative of Static and Dynamic nature. The Political factors recognized from previous research and brainstorming are political system, political stability, maturity of political leadership, threats to the state, unstable neighborhood, Bureaucratic hurdles and government intervention. All these factors are of qualitative nature. Out of all these factors the Political System is considered as static but rest all are considered having Dynamic nature. The static quantitative factors in Economic factors category will be land cost, transportation costs, construction cost, sales & marketing costs and average salaries paid.

The Static Qualitative factors identified as Economic factors are scope for expansion opportunities, competition, impact of present industry status, market characteristics, supplier characteristics, financial incentives, tax structure, currency strength against dollar, economic standing of the country and inflation trend. Role of parallel economy shall be considered as Dynamic Qualitative factor. The Social Factors considered are GDP & per capita income which is of Quantitative and considered to be static. Knowledge base, medical facilities, education system and avenues, Labour characteristics, motivation and enthusiasm of employees, employability, union flexibility, social ethos, linguistic barriers, affect on health of people due to industries, use of vastushastra, impact of religious beliefs on industrial growth, standard of living are static qualitative factors whereas blind belief in leadership, internal turbulence and consumer characteristics are of dynamic nature. The operational Static qualitative factors considered are employee integrity and employee ethics whereas health hazards will be of dynamic nature. In Technological factors, Technology costs and I.T. operational costs are considered as Static Quantitative factors. Energy alternatives & backup, uninterrupted power, labor skill, infrastructure availability, availability of transportation (land/sea/ports) and availability of utilities are of static qualitative nature. In Legal factors, Government Policies and Government Laws & Regulations are considered as Static qualitative factors. In Environmental Factors, factors like Climatic conditions, water availability and impact of industrialization on environment are considered as qualitative factors of static nature and Disaster Risk is considered as qualitative factor of Dynamic nature.

5. RANKING OF FACTORS

Google forms were designed for ranking of factors (importance in locating a facility). The target survey group consisted of Industries /Businessman, Govt. Bodies, NGOs and University Teachers/Residents. The respondents were

asked to input their responses in a scale of 1 to 10 i. e. 1 for lowest influence and 10 for highest influence as shown in sample Table 1. The final value of each factor is based on average of all responses which shows the influence importance.

TABLE 1: Sample Responses

Respondent	Government policies for industry	Govt. Laws and regulations	Political system	Scope for expansion opportunities for industries	Industry competitive scenario	Impact of present industry status
1	10	10	8	10	7	7
2	8	7	6	8	10	10
3	8	7	7	7	7	6
4	8	8	7	9	8	8

6. PROPOSED METHOD FOR RANKING OF FACTORS

The commonly used method of Ranking by paired comparison [D.H. Stamatis] gives results that may lead to similar scores when we have more factors to be considered. This is evident from the fact that the method uses only three numbers i. e. 1 for small difference, 2 for medium difference and 3 for major difference. Further, the method works well with maximum of 15 factors. In the present context, 57 factors are taken into consideration. Hence authors have devised an alternative which takes into account qualitative assessment of target survey group that can counter the disadvantage of the traditional method. From the responses of various stakeholders, the final values of influence importance (IIVs) are calculated as shown in

Table 2. In the next step a matrix of all the factors is formed. In the given matrix, differences between scores are mentioned. If Factor A in the horizontal column is superior to Factor B in the vertical column, then positive difference is mentioned in the corresponding cell pertaining to both and if Factor A in the horizontal column is inferior to Factor B in the vertical column, then negative difference is mentioned in the corresponding cell pertaining to both as shown in sample calculations of Table 3. Then sum of all positive differences pertaining to Factors in the row is calculated. Similarly Sum of all negative differences pertaining to the Factors in the columns is calculated. Finally the negative sums are added as numbers to positive sums as shown in Sample calculations in Table 4 to get final scores and ranking is done based descending scores of factors as shown in Table 5.

TABLE 2: Influence Importance Values (IIVs)

FACTOR	IIV	FACTOR	IIV
Government policies for industry	8.30769231	Power supply	8.5384615
Govt. Laws and regulations	8.46153846	Alternate energy sources and backup	6.4615385
Political system	7.30769231	Infrastructure availability	8.3076923
Scope for expansion opportunities for industries	7.61538462	Availability of transportation facility (road/rail/ports/air)	9.0000000
Industry competitive scenario	7.61538462	Availability of utility services (assistance to main services)	7.6923077
Impact of present industry status	6.92307692	Climatic conditions	7.3846154
Market characteristics (customer proximity/purchasing power)	7.84615385	Water availability	8.0000000
Supplier characteristics (quality/reliability)	7.76923077	Impact of industrialization on environment	7.9230769
Financial incentives	7.69230769	Labour skills	7.8461538

FACTOR	IIV	FACTOR	IIV
Tax structure	7.92307692	Political stability	6.8461538
Trend of currency strength against U. S. Dollar	6.15384615	Maturity of political leadership	6.7692308
Economic standing of the country	6.30769231	Internal threats	6.2307692
Inflation trend	5.61538462	Neighborhood stability	6.3846154
Knowledge base	7.00000000	Bureaucratic hurdles	6.6923077
Medical facilities	5.76923077	Government intervention	6.2307692
Education system and avenues	3.76923077	Role of parallel economy	6.2307692
Labor characteristics (education/training facilities)	7.61538462	Health hazards due to industrialization	7.0000000
Employability	7.61538462	Blind belief in leadership	4.8461538
Union flexibility in industries	6.84615385	Internal turbulence	6.3076923
Motivation & enthusiasm of employees	7.07692308	Consumer spending characteristics (demography/culture)	6.9230769
Transportation costs	7.07692308	Land cost in industrial belt	8.2307692
Social ethos your region (pride in work of any type)	6.61538462	Construction cost for industries	7.5384615
Linguistic barriers	5.38461538	Per capita income	6.8461538
Employee integrity & ethics	7.00000000	Gross domestic product (GDP)	6.8461538
Effect on health of people due to industries	6.84615385	Average salary paid	7.3076923
Use of vastushastra for location selection	4.23076923	Sales & marketing costs	7.1538462
Impact of religious beliefs on industrial growth (sensitive industries like leather, meat etc.)	5.30769231	I. T. Operational costs	7.3076923
Standard of living	6.53846154	Disaster risks	6.4615385
Technology cost (indigenous/imported)	7.76923077		

TABLE 3: Sample Matrix for Positive and Negative Differences

	Government policies for industry	Govt. Laws and regulations	Political system	Scope for expansion opportunities for industries	Industry competitive scenario
Government policies for industry	0	-0.15385	1	0.692308	0.69231
Govt. Laws and regulations		0	1.15385	0.846154	0.84615
Political system			0	-0.30769	-0.30769
Scope for expansion opportunities for industries				0	0
Industry competitive scenario					0

TABLE 4: Sample of Positive and Negative Sums Summation

	Negative sums	Positive sums	Summation
Government policies for industry	0	74.23076923	74.2307692
Govt. Laws and regulations	-0.153846154	82.07692308	82.2307692
Political system	0	31.38461538	31.3846154
Scope for expansion opportunities for industries	-0.307692308	41.84615385	42.1538462
Industry competitive scenario	-0.307692308	41.84615385	42.1538462

TABLE 5: Final Ranking of Factors

FACTOR	SCORE	RANK	FACTOR	SCORE	RANK
Availability of transportation facility (road/rail/ports/air)	111.2308	1	Employee integrity & ethics	22.07692	17
Power supply	86.30769	2	Impact of present industry status	20.07692	18
Govt. Laws and regulations	82.23077	3	Consumer spending characteristics (demography/culture)	20.07692	18
Government policies for industry	74.23077	4	Effect on health of people due to industries	18.23077	19
Infrastructure availability	74.23077	4	Per capita income	18.23077	19
Land cost in industrial belt	70.38462	5	Gross domestic product (GDP)	18.23077	19
Water availability	59.07692	6	Union flexibility in industries	18.23077	19
Impact of industrialization on environment	55.38462	7	Political stability	18.23077	19
Tax structure	55.38462	7	Maturity of political leadership	16.76923	20
Labour skills	51.84615	8	Bureaucratic hurdles	15.38462	21
Market characteristics (customer proximity/purchasing power)	51.84615	8	Social ethos your region (pride in work of any type)	14.07692	22
Supplier characteristics (quality/reliability)	48.46154	9	Standard of living	12.84615	23
Technology cost (indigenous/imported)	48.46154	9	Alternate energy sources and backup	11.69231	24
Availability of utility services (assistance to main services)	45.23077	10	Disaster risks	11.69231	24
Financial incentives	45.23077	10	Neighborhood stability	10.61538	25
Scope for expansion opportunities for industries	42.15385	11	Economic standing of the country	9.615385	26
Industry competitive scenario	42.15385	11	Internal turbulence	9.615385	26
Labor characteristics (education/training facilities)	42.15385	11	Internal threats	8.769231	27
Employability	42.15385	11	Government intervention	8.769231	27
Construction cost for industries	39.38462	12	Role of parallel economy	8.769231	27
Climatic conditions	34.00000	13	Trend of currency strength against U. S. Dollar	8.153846	28
Political system	31.38462	14	Medical facilities	5.461538	29
Average salary paid	31.38462	14	Inflation trend	4.538462	30
I. T. Operational costs	31.38462	14	Linguistic barriers	3.384615	31
Sales & marketing costs	26.61538	15	Impact of religious beliefs on industrial growth (sensitive industries like leather, meat etc.)	3.076923	32

FACTOR	SCORE	RANK	FACTOR	SCORE	RANK
Motivation & enthusiasm of employees	24.30769	16	Blind belief in leadership	1.692308	33
Transportation costs	24.30769	16	Use of Vastushastra for location selection	0.461538	34
Knowledge base	22.07692	17	Education system and avenues	0	35
Health hazards due to industrialization	22.07692	17			

7. CONCLUSION

In this paper, the various qualitative and quantitative factors affecting Facility Location are identified. An alternative for Ranking by paired comparison is devised by the authors and the ranking of factors show the influence of factors affecting location decision in an orderly manner. The findings here, in some way or the other will facilitate the investors in Make in India initiative.

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Emerging Trends for Improving the Operational Efficiency of Construction Projects

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Abstract: Project profit and loss can be decided based on the efficient operations of the site. Mismanagement of works in the site leads to so many problems like cost overrun, time overrun, loss of quality, over production, may reduce idle time for employees, loss of good will etc. Hence we need to utilize the production resources effectively to enhance the operational efficiency in the projects. There are several ways to improve the operational efficiency of the project sites, which leads to higher productivity, lower expenses, improving the efficiency of employees. Some project orientated strategies may be implemented in a friendly environment to push the employees for meeting the work targets. Recent days some of the projects are tracked by electronic applications like mobiles, e-apps, cloud software etc. The ultimate goal of current research paper is to identify the trends to improve operational efficiency to lower the costs, without compromising productivity, quality and profit through Information and communication technology (ICT) tools.

Key words: Operational efficiency, productivity, projects, ICT tools, e-apps

1. INTRODUCTION

Construction industry is one of the booming sectors in the India as well as world. It is projected to grow about US\$ 1.7 trillion from 2015 to 2020 as per the construction Intelligence centre(CIC) report. It is very important for any construction project to maximize their operational efficiency by different means to achieve the higher productivity as well as to retain good profit in the project (Cooper et.al., 2000). All the parties involved in this process should be flexible when employing new policies and open to change as workers may respond negatively to any given proposal. There are many of the strategies which aim to make incremental progress to the overall productivity of a project (Goldratt., 1997). When these steps are put in action by a team, they are given the ability to accelerate any given project and lead to far more efficient results that save both time and money. The project manager need to record the productivity levels and time tracking may help to identify the actual problems (Kotnour., 2000). Breaking down the larger construction works into individual parts can provide insight into how productive a given worker or team may be. Analyzing and studying elements of the entire project enables construction companies to figure out what changes need to be done (Klastorin, 2004). Time tracking provides a clearer picture in terms of how workers are managing their time, creating opportunities for boosting operational efficiency (Pich et. al., 2002). Currently some of the project managers are tracking the progress of projects by adopting latest technologies by communication through mobile devices which ensures that all members of a construction project can connect with each other both on and off site (V Ahuja

et. al., 2009). Instant messaging apps and various other communication tools can be beneficial for construction companies, saving time and eliminating the need for face-to-face interaction which is, often time-consuming. If an effective mobile app or software is implemented, operational efficiency is boosted and reduces unnecessary delays and interruptions. Similarly cloud and construction software technologies provide a myriad of functionalities are quite helpful for higher operational efficiency (Onyegiri and Nwachukwu, 2011). Generation of e-apps for the projects may integrate the project activities and project stake holders effectively. These e-apps are helpful for better keep track of the overall productivity of a given jobsite. By being more in tune with the details of a specific project, opportunities for adjustment and modification may present itself, which may stand to increase operational efficiency in all areas of the project (Smith: 2007)

2. DEVELOPMENT OF PROJECT MANAGEMENT

The project management was shaped significantly after inventing the Gantt chart by Henry L. Gantt (1861-1919). The Gantt chart helps to track the progress of tasks and the allocation of resources to them over time, and is the central tool for visualizing project progress when using project management software (Goh, J. & Hall, N.G. 2012). In the late 1950s DuPont Company developed the critical path method (CPM). This method plans projects without considering either resources or uncertainty in task times. CPM permits the use of a simple algorithm that delivers optimal solutions. Several project management software packages, including the market leader Microsoft Project

(MSP), also use this method as a key step in developing solutions. The program evaluation review technique (PERT) was developed to find the effect of uncertainty in project. Monte Carlo simulation is used as an alternative to PERT. This methodology avoids the worst problems of PERT. Later critical chain Project Management (Goldratt., 1997) was developed for improved performance of projects. Agile project management became popular tool to have minimal planning and documentation in projects (Wikipedia, 2012).

As per the recent study conducted by the World Bank the scale of complexity has gone up in the construction projects from olden days to present days. Mega value and long duration projects are under stress due to environmental safeguards, infrastructure sustainability etc.. Now a days information and communication technology (ICT) tools are dictating the tempo of our lives and projects (S. Bowden et. al., 2006). Many emergency situations are forcing to implement new trends in project management. Under these situations digital tools are playing a key role to improve the productivity in projects (Peleg B. and Sudhölter., 2003).

3. METHODOLOGY

The information and communication technology (ICT) tools are portrayed significant results in integrating the various activities in projects. The ICT tools cover the usage of computer hard ware, software, communication tools for a specific application. The various ICT tools helpful to address these problems are

- Simple Spreadsheet/Data base Systems
- Commercial Off the -Shelf (COTS)E-tools
- Bespoke Systems
- Enterprise Resource Planning(ERP)

3.1 Simple Spreadsheet/Data base Systems

Any project consists of huge amount of data related to various materials and activities. It is very difficult to manage them in spread sheets, required to store then in proper manner. Spreadsheets cannot handle the same. Also records are required to maintain for the ongoing usage. We need to produce the on demand and scheduled reports. Hence proper data base systems helps to store and retrieve the data related to projects. Spread sheets are used to perform the automatic calculations of available data in the form of charts and graphs.

These are basic tools like MS excel sheets to calculate the cost and time of the project. It involves storing the data related to project and is helpful in retrieving the data. It includes products, orders, base reports, invoices etc. It is created in user friendly manner for easy navigation. Hence it helps an efficient way to enter data, store data, and generate information for invoices, sales by product, sales by

customer, and so on for the projects. Excel spreadsheets helps quickly to calculate what changes in price and sales would do to their revenue by creating various scenarios. They could also use their consumption pattern in excel to analyze trends by generating charts and graphs. This provided an easy way to analyze their data and trends in a tool with understandable and meaningful formats. This information is quite helpful to the supervisor and engineer level in the site. Many project managers applied the same techniques in projects on trail basis to get quicker output from the available data. In most cases, using the combination of a database to store your business records and a spreadsheet to analyze selected information works best.

3.2 Commercial Off the -Shelf (COTS)E-tools

These are experimenting tools developed for business purpose and integrated to existing organization systems. These are excel based tools to calculate the request for proposal (RFP), Standard rate of schedule (SOR) project planning and scheduling systems etc.. These tools are tailored to calculate the cost and time of the project. These tools can be integrated with enterprise resource planning (ERP) software for better results. They are helpful in work estimation, document management system, work measurement system etc. some of the benefits of these tools are accuracy of estimates, quick preparation of bill of quantities(BOQ), accuracy of measurements, improved progress tracking and transparency of payments etc. Some of the e-apps available for tracking the projects are view point, field wire, plangrid, safety meeting app, corecon, iHandy carpenter, Build calc, Construction masterpro, BIMxetc..The integration of various activities in the Commercial Off the -Shelf (COTS)E-tools is shown in the Fig1.

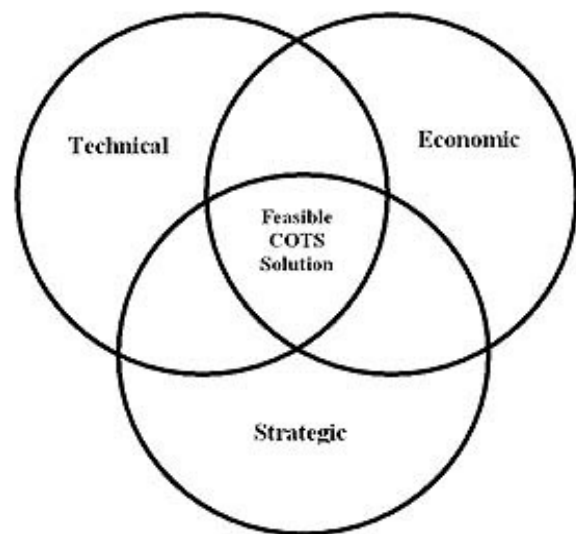


Fig. 1. Integration of various activities in e- tools

3.3 Bespoke Systems

These systems are known for custom made product or service. Currently the project complexity is increasing day by day and expectations are very high, under these circumstances bespoke systems are designed to meet custom specification of small, medium and large scale projects. Bespoke systems proved their significance in business and project applications. The life cycle of bespoke systems is shown in Fig 2.

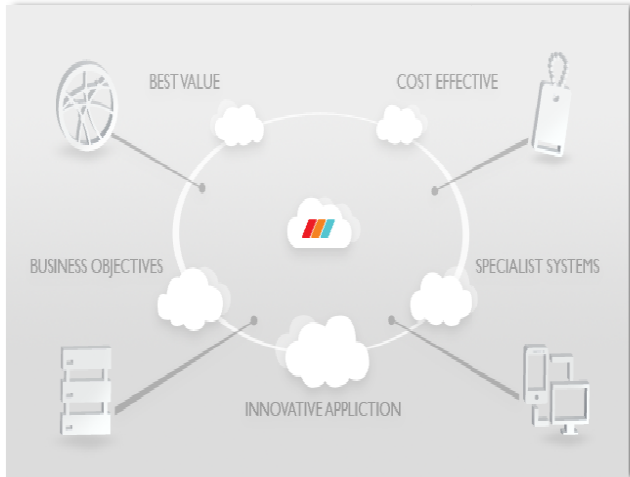


Fig. 2. Life cycle of bespoke systems

Some of the advantages of bespoke systems are as follows.

- Bespoke systems use software which is specially created and customised for construction projects.

- The customised software can adopt any changes in the construction business and allow you to update the software whenever requirements arise.
- The updates in the bespoke software will enhance productivity and reduce the cost involved in the repetitive data entry.
- Bespoke system helps to consolidate business information against one source.
- It helps to get a greater insight into day-to-day progress of the project with customised reporting and business processing tools.

3.4 Enterprise Resource Planning (ERP)

For any construction project, field staff is very important and their productivity plays a vital role for timely completion of the project. Integration of end-to-end operations reduces the risk and maximises the profitability. The construction project consists of a variety of works and requires a variety of skills. Hence, skills and works are to be integrated in line with the delivery schedule of the project. For this purpose, the application of ERP software in the construction projects.

ERP is the integrated management of core business processes in real time mediated software technology. The business activities include product planning, project planning, managing sales, marketing of products, delivery of services, shipping and payment, finance etc.. So the complete business administration is good in these ERP systems. The various challenges and applications of e-tools in construction projects are portrayed in Table 1.

TABLE 1: Challenges and Solutions

Challenges	Problem faced	Application of e- tool	Functionality to be adopted	Data required
Delays in execution	Lack of master plan. Delays in designs and drawings	Time management systems	Templates for estimation and drawings	Standard rate of schedule (SOR) BoQ validation Document
Improper resource allocation	Poor resource planning	Project management systems	Updation of planning and scheduling	Planned Vs actual progress report
RFI and Poor scope	Lack of standardised contractors	Ms office templates BOQ automation	Collecting the standard data	Design reviews
Communication management	Lack of information collection and sharing	Content management systems(CMS)	Tracking the performance and generating status reports	Milestone reports Financial reports Budget reports
Procurement delays	Faulty choice in contract type Lack of consistency in application of tender rules	e- procurement systems	Online bid submission, evaluation Invoicing the payments	Tender notices, SBD, RFP

Challenges	Problem faced	Application of e- tool	Functionality to be adopted	Data required
Managing project risks	Lack of risk management tools and practices	Risk management systems	Record and quantify the risk occurrences&Predict the risk occurrence	Analysis of risk assessment Generation of reports
Project Integration	Progress is not updated properly	ERP systems	Day to today work updating by concerned in charge	Data from work location

4. CONCLUSIONS

There are multiple approaches that are emerging in the area of project management to improve the operations of the projects. These improvements are helpful from conceiving to the commencement of the projects. The current paper highlights the application of some of upcoming trends and their implementation in construction projects. The application of various e-commerce tools mentioned in the research paper proven significant improvement in operational efficiency in construction projects and other projects as well. The project manager has to realize the benefits and its impact on the project in the long run for better solutions. The new project management approaches provide the tools and environment to plan, monitor, track, and manage schedules, resources, cost and quality. In the paper presented some of the tools have proven to be successful and output gave the satisfactory results during implementation. It serves as benchmark for project manager for future planning as well as good documentation.

During the execution of the projects the proposed e-tools and project oriented apps are to be developed and installed by the concerned project members to get updated details about the project. These updates are uploaded by concerned in-charges of the project to provide updated information to others who are involved in the project from time to time. It helps to monitor and improve the project activities in a better way for improving the operational efficiency.

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Reliability Centered Preventive Maintenance for Pressure Relief Valves

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Abstract: Maintenance in a Pressure Relief Valve plays a key role as it is the last line of defense against overpressure and loss of containment. The interval of maintenance for the pressure relief valves was studied from the date of installation to the last maintenance carried out. This research intends to optimize the preventive maintenance interval by calculating the governing probability of failure based on which the next maintenance interval is decided. Design, maintenance and operating changes resulting from data and failure analysis can provide significant reliability improvements and reduced costs over the lifetime of a valve.

Keywords: Reliability centered maintenance, Preventive maintenance, Probability of Failure, Cost Optimization, Risk based inspection

1. INTRODUCTION

Components and parts of most of the equipment deteriorate due to utilization and could lead to breakdown. Preventive maintenance is used to reduce the rate of unexpected failure which is more economical compared to breakdown failure (National Research Council, 1991). Downtime due to breakdown affects the productive capability of physical assets by reducing output, increasing operating costs and affecting customer service. The effects of downtime are being aggravated by the worldwide move towards just-in-time systems, where reduced stocks of materials throughout the supply chain mean that quite small equipment failures are now increasingly likely to interfere with the operation of an entire facility (Moubray, 1997). The cost of maintenance is rising steadily it is one of the highest cost according to the proportion of expenditure that an industry has to incur.

There are multiple types of maintenance strategies that have been utilized in industry mainly (1) Breakdown/Reactive maintenance (2) Preventive maintenance (3) Proactive maintenance (4) Predictive maintenance (5) Reliability Centered maintenance. Preventive maintenance was put to use so that the breakdown of machine and equipment is prevented. Although preventive maintenance has potential benefits of uninterrupted production there are disadvantages involved such as need of high labor, and huge upfront cost for regular maintenance. For equipment those do not hinder the production rate and the safety of workers and environment do not require the extensive predictive maintenance strategy as it is not cost effective. Therefore, in this case where the equipment is not critical breakdown maintenance ideology is used. For optimal maintenance of a plant the above-mentioned strategies are utilized based on the criticality and the significance of the equipment in the

production process, as an outcome Reliability Centered Maintenance originated. (Vishnu C. R., 2016)

One method for relating reliability to PM is known as Reliability-centered maintenance (RCM). RCM is a qualitative systematic approach to organizing maintenance (Moubray, 1997) (Nowlan & Heap, 1978) (Smith, 1993). It originated in the aviation industry in the 1960s with the introduction of the Boeing 747 series, and the need to lower PM costs in attaining a certain level of reliability. The results were successful and the methodology was developed further. In 1975, the U.S. Department of Commerce defined the concept RCM and declared that it should be used in all major military systems (Nowlan & Heap, 1978).

Reliability centered maintenance is a high-level maintenance strategy that is meant to optimize all the available equipment in the facility. A variety of maintenance approaches are used to put together an overall approach that is conducive for every different system and equipment category. These maintenance strategies are optimized provide most overall efficient functioning of the plant.

The goal of RCM philosophy is to provide the stated function of the facility, with the required reliability and availability at the lowest cost. RCM requires that maintenance decisions be based on maintenance requirements supported by sound technical and economic justification.

Today most of the manufacturing industries relies mainly of automation of the required processes and reduction of manpower generally required. This has led to copious equipment being engaged for functioning of a machinery. Therefore, the reliability of subsystem is extremely important.

If preventive maintenance is being conducted regularly as planned then the unplanned maintenance/repair work hours are reduced. If more preventive maintenance is done then the actual planned repair hours is reduced as well. But if excessive maintenance on an equipment is done then failures can be induced which would be expensive to reform or else excessive money would be spent in over maintaining the equipment which could also be expensive. (Guo, Li, & Wolf, 2016)

Providing spare parts and components under preventive maintenance which can be an effective way to reduce the operating cost, as maintenance and operation are interdependent. (J.Xie & Wang, 2008). Tsai et.al has studied the cost of preventive maintenance components using genetic algorithm (Tsai & K.Wang, 2001). (H.Li, M.Li, Q.Liu, & Li, 2010) proposed an integrated model to balance the preventive maintenance and production scheduling.

The Reliability Centered Maintenance (RCM) applied here for maintenance of pressure relief valve (PRV) thru proper study of Failure Modes and Effect Analysis (FMEA) reliability analysis approach. This analysis identifies the various failure modes affecting PSV, along with the causes and consequences, and the entire system.

2. FAILURE MODE EFFECT ANALYSIS

It is planned to determine and understand the possible failure modes and their causes and the effects of these failures on the system or the user for a given process. It is used to evaluate the risk associated with the identified failure mode its effects and causes, and seek for possible corrective measures of the most serious concerns (Smith J. , 2013).

Fig. 1. FMEA is a ground-up method of preventive quality

assurance (Wirth, Berthold, Krämer, & Peter, 1996). This method does not allow the evaluation of the reliability function of a complex system but it allows to identify and analyze all the system faults, evaluate their importance in the reliability of the system and then focus on maintenance practices and their effect on system reliability. Moreover, FMEA allows to deal with uncertainty due to imprecision associated with the complexity of the systems as well as vagueness of human judgment.

FMEA uses data from the equipment in operation to individualize the more relevant faults of the system without theoretically modelling the cause-effects relationship of failures. The effectiveness stems from the real operation based approach: it allows to select cost-effective actions aimed to correct the maintenance.

Recent studies and findings display a rise in interest of the applications of RCM and FMEA to new fields, such as the petrochemical industry (Kangavari, S. Salimi, & Askarian, 2015), automotive industry (Belu, Ionescu, & Misztal, 2015), electrical engineering industry (M. Bujna, 2014), , pharmaceutical industry (T. Yesmin, 2013).

There are many pressure relief valves in a process industry at different stages of the operation which helps to regulate pressure at the desired value. The FMEA of the Pressure relief valves is important for safe and reliable operations of an entire process plants. In process industry usually, the Pressure relief valves are repaired mostly than replaced, and replaced if it has been subjected to structural damages and in case of non-availability of spares. Therefore, the main FMEA function is to analyzing the failure mode and the likelihood of failure being discovered before occurrence. In this study the general failure modes of Pressure relief valves are being classified into mechanical, calibration and other general failure modes.

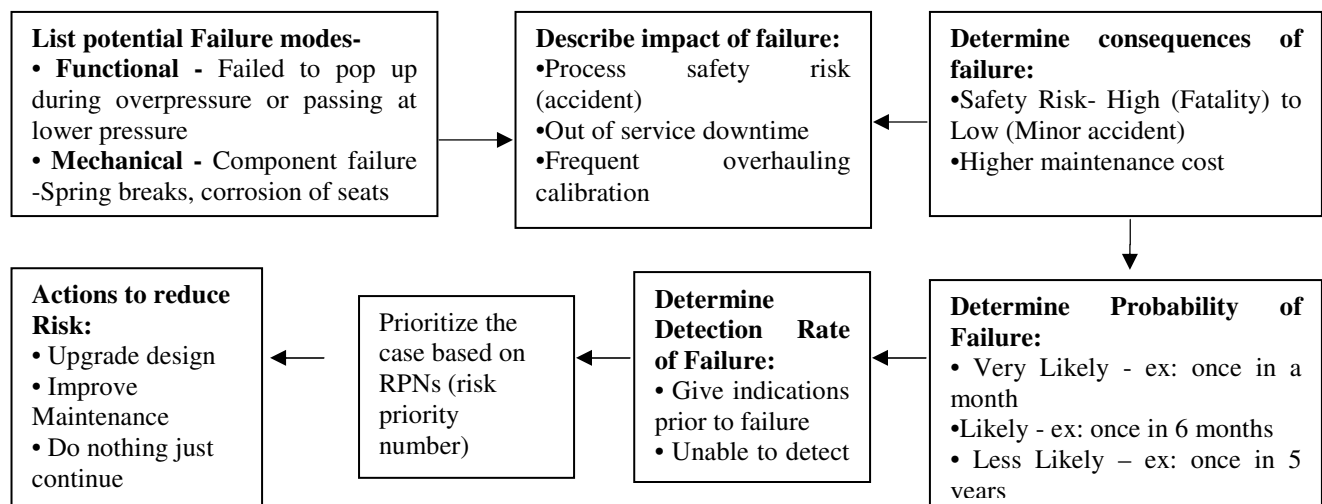


Fig. 1. FMEA methodology

3. RISK BASED INSPECTION (RBI)

Risk based inspection process points out, analyses and maps industrial risk (due to various factors) which can compromise equipment capability in pressurized equipment and structural strength. RBI states these risks which can be controlled through thorough analysis and inspection. RBI can state if inspection is needed if additional data and parameters are provided which is targeted towards underlying uncertainties related to the risk about the present and future anticipated damage state of the equipment. RBI should not be utilized to recommend an inspection which does not elucidate the damaged state of the equipment.

In situations where probability of failure is the driving factor RBI should suggest other reduction options like repair, replacement or actions which reduce the risk criteria. RBI is utilized to prioritize inspection related activities, usually noninvasive techniques as audiometer to detect the passing of PRV or process instrumentation (such as pressure recorder of system) to detect the failed to open during overpressure. The plan which results includes the type of scheduling of inspection for an equipment. In addition to Noninvasive examination additional risk mitigation activities identified by an RBI analysis and depending upon the situation may include change in material of construction, installation of corrosion resistant liners, operating condition changes, injection of corrosion inhibitors.

Consistency and repeatability of analysis are critical to produce an effective RBI program, as RBI is based on relative risks. The overall objective of the maintenance process is to increase the profitability of the operation and optimize the total life cycle cost without compromising safety or environmental issues, this principle is in accordance with RCM philosophy. (Overview of Risk-Based Inspection (RBI), n.d.)

4. THE P-F CURVE

The P-F Chart is one of the most important tools for a reliability centered maintenance plan. It displays the relationship between machine breakdown, cost, and how it can be prevented. The same methodology can be used for PRV overhauling and calibration cycle.

As the machine is working producing desirable output today, does not mean that failures are not already beginning to occur within the system. Most of the machines give some sort of warning that they are in the process of occurring or are about to occur. If evidence can be found that something is in the final stages of failure, it may be possible to take action to prevent it from failing completely and/or to avoid the consequences.

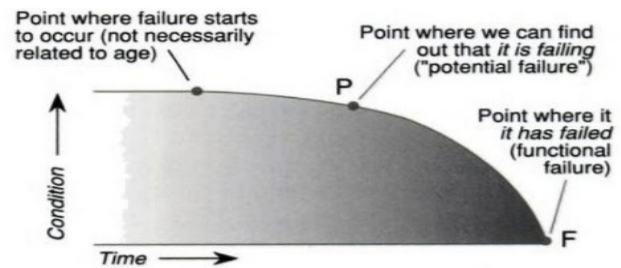


Fig. 2. PF Curve

The failure analysis done in the pressure relief valve is based upon the principles of PF curve. Usually the deterioration of the Pressure relief valve is detected at the point P. If it is not detected at point P then the pressure relief valve starts to drastically deteriorate until point F and then fail eventually. Early signals of failure are where the industry needs to focus so that Pressure relief valves can be kept running at full capacity and minimize downtime (Moubray, 1997).

5. CASE STUDY

The main objective of the study is to evaluate the feasibility of increasing the maintenance time of Pressure relief valves. For this purpose, the working, inspection procedures and routine maintenance procedure was studied. Later, probability of failure of various PRVs were determined for their multiple inspection iteration and all the data was compiled. The governing probability of failure was decided according to the calculated probability of failure-failed to open when required & leak. This leads to economic usage of the funds allotted for maintaining the PRVs as calculated number of routinely maintenance ensures prolonged life and safety of PRVs.

These failure criteria have been taken into account by considering the API 581-RBI standards.

5.1 Probability of failure on Demand

The fail to open (FAIL) failure mode is the primary concern since this failure results in the potential of over pressuring protected equipment and loss of containment. Included in this case is the instance when a valve only opens partially (VPO), where consequences are not as severe, but equipment may be over-pressured nonetheless.

API RBI considers data indicating a partially open valve as a failure to open. Data that indicates a valve opened above set pressure (OASP) is included in the fail to open failure mode since the probability of failure curves are based on bench test data where a failure is defined as any test requiring a pressure greater than 1.3 times the set pressure. A test point that opens above set pressure but does not exceed 1.3 times the set pressure is considered a successful test and is not included in the fail to open (FAIL) case.

Consequences associated with the failure to open failure mode include the effects of fires and explosions on personnel and equipment and the exposure of personnel to toxic fluids as a result of loss of containment. A secondary concern is a failure of the PRD to contain the process while operating at normal conditions.

The API RBI methodology groups the remaining three failure modes together into the LEAK category. Leakage past the valve (LPV), spurious or premature opening (SPO) and valves that stuck open (VSO) are failures that will not result in overpressure or loss of containment from the protected equipment, but will result in potential unacceptable leakage from the process system. The consequences of leakage through a PRD can range from a minor nuisance, causing some loss of product, to a more severe consequence resulting in a process shutdown to repair or replace the PRD. If the PRD discharges to atmosphere, additional consequences may be environmental impact and potential for fires, explosions and toxic exposure.

For the procedure of calculation of probability of failure API 581 should be referred thoroughly from pages 1-40 to 1-41.

5.2 Probability of Leak

A secondary concern is a failure of the PRD to contain the process while operating at normal conditions. The API RBI methodology groups the remaining three failure modes together into the LEAK category. Leakage past the valve (LPV), spurious or premature opening (SPO) and valves that stuck open (VSO) are failures that will not result in overpressure or loss of containment from the protected equipment, but will result in potential unacceptable leakage from the process system. The consequences of leakage through a PRD can range from a minor nuisance, causing some loss of product, to a more severe consequence resulting in a process shutdown to repair or replace the PRD. If the PRD discharges to atmosphere, additional consequences may be environmental impact and potential for fires, explosions and toxic exposure.

For the procedure of calculation of probability of failure API 581 should be referred thoroughly from pages 1-42 to 1-43.

6. RECOMMENDATION

The next date of inspection has been recommended according to API 510 standards.

TABLE I: Recommendation of next Inspection Date

SAP TAG NUMBER	LAST INSPECTION DATE	NEXT INSPECTION DATE	REMARKS	GOVERNING PROBABILITY OF FAILURE
PRV1001	May-15	May-19	Frequency could be Increased from 2 years to 4 years	0.622
PRV1002	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.165
PRV1002B	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.605
PRV1003	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.615
PRV1007	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.481
PRV1201A	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.61
PRV1201B	May-16	May-20	Frequency could be increased from 2 years to 4 years	0.424
PRV2001A	May-17	May-21	Frequency could be increased from 2 years to 4 years	0.54
PRV2001B	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.614
PRV2002A	Dec-16	Dec-18	Frequency is to be maintained at 2 years interval	0.9497
PRV2002B	Dec-16	Dec-18	Frequency is to be maintained at 2 years interval	0.786
PRV2003	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.6113
PRV2003B	May-15	May-19	Frequency could be increased from 2 years to 4 years	0.5504
PRV2004A	Dec-15	Dec-19	Frequency could be increased from 2 years to 4 years	0.6282

7. CONCLUSION

Effective RCM approach ensures the desired performance of the system of interest at a low-cost level. This paper has utilized the API risk based inspection Technology in

optimizing the preventive maintenance interval of pressure relief valves.

The only prerequisites that are required for these calculations are the previous dates of inspection so as to understand the time intervals of inspections, set pressures of

the PRVs, operating pressures of the lines at which the PRVs were operated and the pressure at which the PRV popped during the routine maintenance with which the type of failure (Demand & Leak) can be determined. Following the above based procedures, the probability of both the cases can be determined.

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Total Productive Maintenance (TPM) for Achieving Overall Equipment Effectiveness (OEE)

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Abstract: TPM is a holistic approach to equipment maintenance that strives to achieve perfect production. - No breakdown, - No small stops or slow running, - No defects

In addition it values a safe working environment: - No accident

To improve the system of maintaining and the integrity of production and quality systems through the machines, equipments, processes and employees in any industry TPM is applicable. OEE is as ratio of fully productive time to planned production time. OEE is a measure to evaluate the productiveness of the a machine or a process area. OEE is for the perfect production. OEE takes into account all losses resulting in a measure of truly productive manufacturing time.

Keywords: total productive maintenance, overall equipment effectiveness

1. INTRODUCTION

All company wants to leading positions in the global market based on very highly effective manufacturing system. Japans style of management is very effective for increasing production. TPM is an activity in which administration to worker involvement is necessary. TPM brought to industry overall equipment effectiveness (OEE) as a measure that combines losses from unplanned downtime, reduced speed, and quality. Due to the TPM activities main six big losses which effect to the overall equipment effectiveness are remove or reduced (breakdowns, set up, minor stoppage, speed, defect and speed decrease). TPM for achieving maximum OEE. Renew and repair equipment condition for running production. Dealing with very complex equipment is needed very expert or experience person. Motivation for team member and worker is very effective for early equipment maintenance and good quality products. When early equipment maintenance is done so chance for breakdown is reduce or remove.

Continues improvement of industry is possible when worker to administration involved in manufacturing. “ I used it, you fixed it” mentality is changed by training and education, when user take observation of own machine then it increased performance and quality of product. The operator and maintainer are trained to identify problems related to OEE and performs root cause analysis in terms to find the losses.

Master plan for maintenance is very important for the industry. For master plan skills, quality, assurance and

schedule is importance steps. PM analysis in p- problem, phenomenon, physical

And m- machine, man, mechanism, material which done in each piece of equipment is very effective for planned maintenance.

2. LITERATURE

The Nippondenso Co. Ltd. is japanes company they implement TPM first time. Japan institute of plant engineers (JIPE) was awarded TPM. The paradigm idealized plants in which equipment overall effectiveness is maximized. In paradigm history of TPM is describe which mainly focused on zero breakdown, zero defect and zero accident concept. Return cost is maximise then investment on equipment cost it is possible through the TPM activities. Continues monitoring techniques implement in industry based on the human five senses. Equipment life increased due to TPM paradigm. High availability, high overall equipment effectiveness, low energy consumption and rare accidents are due to the TPM PARADIGM. Equipment replacement, equipment renovation, preparation for lubrication and equipment assembly is in TPM PARADIGM.

In 1971 TPM seeks the key goals which are (1) maximize OEE, due to increased performance, quality and availability (2) involve all level of management and worker (3) involved operations, material management, maintenance, engineering, and administration in equipment management (4) improve equipment performance through small group activities and team performance. Operator trained for how to identified problems earlier before they become serious.

Delay times are reduced and productivity is increased due to autonomous maintenance. Downtime and cycle time reduced than availability and performance increased. Four stages which are preparation, preliminary implementation, TPM implementation, and stabilized are nakajima suggested for implementation of TPM. TPM policies defined for medium and long range planning. “To reduced losses by eliminating breakdown, defect, and accidents while improving employees mindset”

TPM is not only maintenance, cost reduction program it is permanently improvement and maintains the overall equipment effectiveness through whole organization involvement. A planned-maintenance stop or “pit stop” on the NASCAR circuit in 1950 was near by four minute long. And now it is 17.5 to 22.5 seconds. Now a days that is less than 20 seconds it is increased performance rating.

3. METHODOLOGY

TPM focuses on optimizing planning and scheduling. Availability, performance and yield are other factors that affect productivity. Availability losses arise from breakdowns and change-over, i.e., the situation in which the line is not running when it should be. Performance losses arise from speed losses and small stops or idling or empty positions. Yield losses consist of losses due to rejects and poor startup behavior in the line producing the products. These losses lead to low values of the overall equipment effectiveness (OEE), TPM helps to raise the value of the OEE by supplying a structure to facilitate the assessment of these losses. Application of TPM leads to both shortand long-term improvements. TPM entails having a (i) Linear organizational structure. (ii) Multi-skilled workforce. TPM seeks to boost the setting of aggressive, but attainable, goals for raising the value of the OEE.

4. OEE CALCULATIONS-

Step-1 For the calculation of OEE mainly availability quality rate and performance efficiency is required.

$O. E. E. = \text{Availability} \times \text{Quality rate} \times \text{Performance efficiency}$

Step-2 operation time is calculated by the loading time and unplanned down time.

$\text{Operation time} = \text{Loading time} - \text{Unplanned down time}$

Step-3 availability efficiency calculated by ration of operation time and loading time.

$\text{Availability} = \text{Operation time} / \text{Loading time}$

Step-4 quality rate calculated by input, quality defects and production input.

$\text{Quality rate} = (\text{Input} - \text{Quality defects}) \times 100 / \text{Production Input}$

5. CONCLUSION

Success of TPM depends on various pillars like 5-S, Jishu Hozen, Planned Maintenance, Quality maintenance, Kaizen, Office TPM and Safety, Health & Environment. Overall Equipment Effectiveness has improved from 63% to 79% indicating the improvement in productivity and improvement in quality due to the tpm activities. It is observed that most of the losses are reduced by planned maintenance and autonomous maintenance .training and education is most required for the TPM implementation. Whole TPM activities are effect on availability, quality and performance. Dynamic model of total productive maintenance is implemented due to this for example maintenance department, engineers and operators can jointly work in organization.

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Multi-Manned Assembly Line Balancing: Minimization of Workforce, Case Study on an Automobile Plant

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Abstract: This paper is mainly focused on optimization of the “number of workers” working on multi-manned assembly line. This will help the industry to fulfill requirement of extra workers in other departments. Binary integer programming method is used to get optimum number of workers. Mathematical formulation of objective function and constraints are coded into Lingo. Branch and Bound algorithm is used on Lingo to solve the problem. The result of case study shows that almost 17% extra workers are working on the line. For an automobile plant this number is huge. It affected the efficiency and space utilization inside the plant. The current research work will motivate other organizations to use the scientific techniques and published works for the optimization of their assembly line and production system. Data for the case study is taken from an automobile plant.

Keywords: Integer programming, Branch and Bound, Multi-manned assembly.

1. INTRODUCTION

Plants producing large size products and having high production volume are generally using multi-manned assembly line (MAL) system. In multi-manned assembly line more than one workers are working on a single workstation and performing different tasks on a single product simultaneously. In order to established multi-manned workstation assembly line system almost every industry are using conventional method (Mastor. A. 1970). In conventional method of assembly line balancing (ALB) every worker is allowed to work on a single workstation. Conventional methods have many basic constraints and assumptions which are very different from real life assembly line. Scientific methods of balancing assembly line is more generalized and realistic which is presented in this paper for minimization of workers.

This paper proposes a case study of an automobile plant ‘XYZ’¹ located in India. Author visited plant to collect data and see the different types of constraints available on existing assembly line. According to observation, mathematical model of assembly line constraints are developed. The developed models are checked with pre-existing standard problem of literature and then applied for case study.

2. LITERATURE REVIEW OF MULTI-MANNED ASSEMBLY LINE

The world can rarely think about function and production without multi-manned assembly line. Every small and big

industries are used to it. Despite the fact it is used every where, its hard to find literature available on multi-manned assembly line problems. In this section literature available on MALBP are discussed in brief. Literature available on multi-manned, straight layout of line and line which produces single products are presented only.

According to available literature on MALBP, Dimitriadis (2006) presented first time these type of workers arrangement on assembly line. In this paper workers are arranged in different group. Each groups are performing different tasks on different workstations. Paper also presented two level heuristic approach. Assignments of tasks to workstations and assignments of tasks to workers are done by these two level heuristic. The methods proposed by researcher results in space utilization improvement while effectiveness of assembly line in terms of number of workers and idle time remain same.

Fattahi et al. (2011) proposed mathematical model and ant-colony algorithm for MALBP. Paper compare the solution of same problem by solving with two different method. Two different methods are mixed-integer programming and developed algorithm. Proposed mathematical model having multi-objective function with minimization of workers and minimization of workstation. It is observed that the developed algorithm gives exact solution for small size problem. For large size problem ant-colony gives feasible solution near by optimum solution. It also shows the results for better space utilization and workers reduction on assembly line.

¹ ‘XYZ’ is changed name of an automobile company

Qin et al. (2011) presented genetic algorithm mixed with heuristic procedure for MALBP for minimizing the number of workers on assembly line. Algorithm uses roulette wheel selection methods for the generation of initial solution. After that it integrated the heuristic and decode the initial solution several time to get final solution. Developed algorithm shows the improvement in system and reduction in workers on assembly line.

Kelleoguz et al. (2014) proposed new constructive genetic algorithm based on heuristic and also presented some new mathematical constraints to make assembly line more generalized. The developed algorithm directly present the solution into Gantt chart form. Solution is compared with ant-colony and exact solution procedure. It is found that developed algorithm performed well in terms of workers reduction. Results in terms of reduction of workstations shows the poor performance.

Roshani et al. (2016) developed simulated annealing algorithm for MALBP. Based on proposed algorithm, two meta-heuristic procedure is developed. Indirect simulated annealing (ISA) and direct simulated annealing (DSA). In this paper the algorithm is used to solve the Type-II problem of assembly line which is minimization of cycle time. It is observed that both ISA and DSA algorithm gives the optimum result for small size problem. Performance of DSA and ISA is also compared in this paper. When authors fixes the number of workers on assembly line performance of DSA is better than ISA and vice versa.

Chen (2017) proposed a hybrid heuristic approach. This approach combines the method of building the initial feasible solution and simulated annealing algorithm. The introduced algorithm are using several parameters. To find the optimum combination of parameters design of experiment (DOE) and taguchi methods are used.

Literature present above and reviewing others part of literature on MALBP, almost all the authors uses heuristic algorithm to solve the assembly line problem. It is very hard to find some paper with real life implimentation of assembly line case study. This develops the gap between research done and real problem of industry. Aim of this paper is to solve real life assembly line problem for minimizing the number of workers working on line and reduce that gap.

3. MATHEMATICAL MODEL OF MULTI-MANNED ASSEMBLY LINE

The proposed mathematical model is developed according to the requirement of the situation present in the plant. Problem is solved for minimization of workers on line, so a single objective function is developed. Apart from basic constraints of multi-manned assembly line, constraints like group working is used. Kim et al. (2009) proposed a mathematical model for two-sided assembly line, which

further modified for multi-manned assembly line by Fattahi et al. (2011), is used and developed here to solve the problem. Constraints (8) and (10) are two new constraints given by Yilmaz (2016).

Indices

i, h : tasks.

j : Stations.

k : Workers.

Parameters and sets

I : Set of task.

J : Set of workstations.

K : Set of workers.

t_i : Task time.

ct : Cycle time.

$P(i)$: Set of immediate predecessor of task i .

$P_a(i)$: Set of all predecessor of task i .

$S(i)$: Set of immediate successors of task i .

$S_a(i)$: Set of all successors of task i .

Decision variables

st_i : Starting time of task i .

x_{ijk} : $\begin{cases} 1, \text{if task } i \text{ is assigned on station } j \text{ to worker } k \\ 0, \text{otherwise} \end{cases}$

w_{jk} : $\begin{cases} 1, \text{if station } j \text{ is assigned to worker } k \\ 0, \text{otherwise} \end{cases}$

ws_{jk} : $\begin{cases} 1, \text{if station } j \text{ is assigned to } k \text{ workers} \\ 0, \text{otherwise} \end{cases}$

y_{ih} : $\begin{cases} 1, \text{if task } i \text{ perform earlier than task } h \text{ by the worker } k \\ 0, \text{otherwise} \end{cases}$

Objective Function

$$\text{Minimize } \sum_{j \in J} \sum_{k \in K} w_{jk} \quad (1)$$

The goal of objective function (1) is to reduce the number of workers by using the constraints given below.

$$\sum_{j \in J} \sum_{k \in K} x_{ijk} = 1, \forall i \in I \quad (2)$$

$$\sum_{j \in J} \sum_{k \in K} j * x_{hjk} \leq \sum_{j \in J} \sum_{k \in K} j * x_{ijk} - 1, \forall i \in I, h \in P(i) \quad (3)$$

$$st_i + t_i \leq ct, \forall i \in I \quad (4)$$

$$st_i - st_h + A * \left(1 - \sum_{k \in K} x_{hjk}\right) + A * \left(1 - \sum_{k \in K} x_{ijk}\right) \geq t_h, \quad (5)$$

$$\forall i \in I, h \in P(i), j \in J \quad (5)$$

$$st_h - st_i + A * (1 - x_{hjk}) + A * (1 - x_{ijk}) + A * (1 - y_{ih}) \geq t_i, \forall i \in I, h \in \{r | r \in I - (P_a(i) \cup S_a(i) \text{ and } i < r), j \in J, k \in K\} \quad (6)$$

$$st_i - st_h + A * (1 - x_{hjk}) + A * (1 - x_{ijk}) + A * y_{ih} \geq t_h, \forall i \in I, h \in \{r | r \in I - (P_a(i) \cup S_a(i) \text{ and } i < r), j \in J, k \in K\} \quad (7)$$

$$\sum_{i \in I} x_{ijk} - m * w_{jk} \leq 0, \forall j \in J, k \in K \quad (8)$$

$$\sum_{i \in I} x_{ijk} - w_{jk} \geq 0, \forall j \in J, k = 1, 2, \dots, M_{max} - 1 \quad (9)$$

$$\sum_{k \in K} k * ws_{jk} - \sum_{k \in K} w_{jk} = 0, \forall j \in J \quad (10)$$

$$\sum_{k \in K} ws_{(j+1)k} \leq \sum_{k \in K} ws_{jk}, j = 1, 2, \dots, J - 1 \quad (11)$$

$$w_{j(k+1)} \leq w_{jk}, \forall j \in J, k = 1, 2, \dots, M_{max} - 1 \quad (12)$$

$$x_{i1jk} - x_{i2jk} = 0, \forall (i1, i2) \in ZP \quad (13)$$

$$x_{i1jk} + x_{i2jk} \leq 1, \forall (i1, i2) \in ZN \quad (14)$$

$$st_i \geq 0, \forall i \in I \quad (15)$$

$$x_{ijk} \in \{0, 1\}, \forall i \in I, j \in J, k \in K \quad (16)$$

$$y_{ih} \in \{0, 1\}, h \in \{r | r \in I - (P_a(i) \cup S_a(i) \text{ and } i < r)\} \quad (17)$$

$$w_{jk} \in \{0, 1\}, \forall j \in J, k \in K \quad (18)$$

Constraints (2) is assignments constraint it makes sure that each task is assign to a single workstation to a single worker. Every assembly line problem have a set of tasks and they are having some sequence to perform them. Constraints (3) ensure that all the tasks follow the sequence and known as precedence constraints. All the stations have fixed amount of time within that time task have to perform. The fixed time is called cycle time, which is taken care by constraints (4). Constraints (2, 3, and 4) are generally present in every assembly line problems. Constraints (5, 6, and 7) are the sequencing constraints. If task (i) is immediate, successor of task (h) and they all are assign on same workstation than constraints (5) become active for every such set of task. When this satisfied, the constraints

(5) reduced to $st_i - st_h \geq t_h$. Constraints (6, 7) are used when there is no precedence relation between tasks. Constraints (6) become active if task (h) is assign earlier than task (i) in other case constraints (7) is active. Constraints (8, 9) control the distribution of worker while aim of constraints (10, 11) is to verify the number of workers used in each station and load the stations in an increasing manner respectively. Constraints (12) control the sequence of worker. Constraints (13, 14) are positive zoning and negative zoning constraints respectively. These ensures that which set of tasks are done togethe. Starting time of each task must be greater than zero is ensure by constraints (15). Constraints (16, 17, and 18) are binary integer variables.

4. CASE STUDY

In this section, a case study is presented to illustrate how research work can be implemented to real life problem and how it improve the system.

4.1 Problem Description and Data Collection

The problem is to study the assembly line of an automobile plant 'XYZ'. The plant is building special type of trucks. Currently assembly plant is working into four sections. Frame section, Stand I section, Stand II section and Stand III section. Every sections have fix number of tasks and that can be done in that section only due to resoucrs available for doing that tasks. Every tasks comparies of many sub-tasks. Deatil of each tasks and sub-tasks are given in Table 1 with their tasks time. Task time is recorded by stop watch. Each task time is recorded three times and average time is taken for solving the problem.

TABLE 1: Details of tasks and sub-task with number of workers

Sections	Major Task	No. of Sub-tasks	No. of workers	Task time(min)
Frame section	A	40	26	44.31
	B*	25		42.7

Sections	Major Task	No. of Sub-tasks	No. of workers	Task time(min)
Stand -I	C	58	51	23.36
	D	3		9.16
	E	17		23.4
	F	3		5.28
	G*	12		6.93
	H	6		9.35
	I	4		34.35
	J	6		7.5
	K	4		4.7
	L	5		3.4
Stand -II	M	4	60	10.55
	N	7		7.6
	O*	5		3.56
	P	5		6.2
	Q*	6		3.98
	R	6		4.85
	S	3		9.95
	T	3		0.71
	U	7		19.13
Stand-III	V	4	49	9
	W	4		5.03
	X	7		13.75
	Y*	10		19.56
	Total	254	186	328.31
*substation				

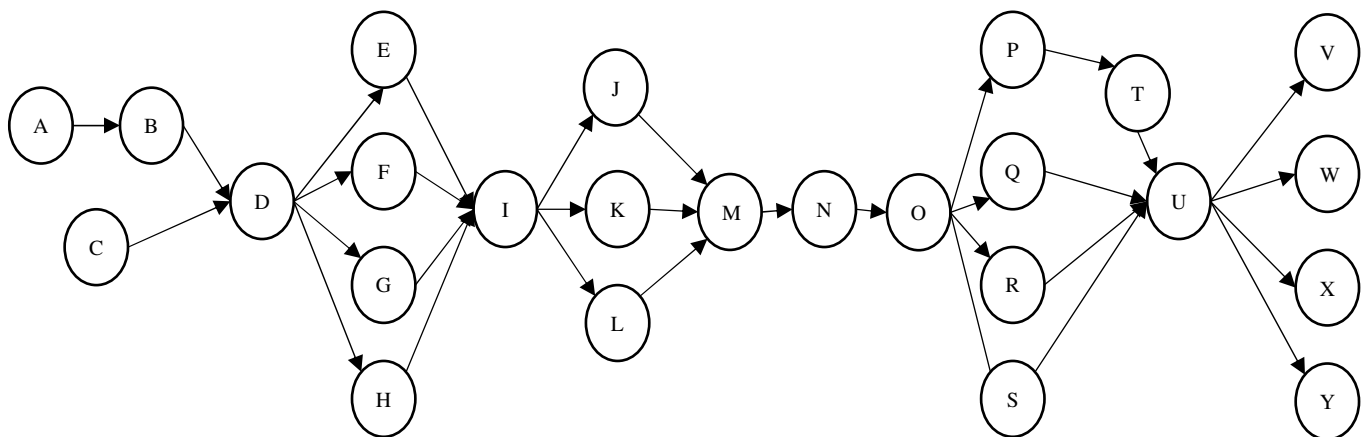


Fig. 1. Precedence relation among tasks

Fig 1. Shows the precedence realtions amoung various tasks. There are 25 more precedence relation of sub-tasks. Those realtions are not shown because of privacy and policy of assembly plant. As soon in Table 1 every tasks and their sub-tasks must be done together in that sections only. Automobile plant not agree to change the plant layout and design. Only things in author can do that reduced the number of workers used on assembly line with same arrangement of workstations and plant layout.

4.2 Solution Procedure of Case study

All the precedence relations are checked for parallel task using constraints (6, 7). Whereever possible many large tasks are divided into small sub-tasks to reduce to workload on a single workers and to reduce task time. Make the sets of tasks that are bound to done together. Similarly make the sets of tasks that having parallel realtions and sets of tasks that do not have any precedence realtion. These sets are input for Lingo program. There are various assumption under which the case study is carried out.

1. The problem is solved for manual assembly line.
2. The work piece should be placed in a particular position in order to perform a task.

3. Product and resource repositioning time are also not considered.
4. Breakdown time and non-productive time are not considered while solving problem.
5. Problem is solved for single model, straight line layout.

Minimization of workers are carried out in two part. (A) Solve each task precedecnce by considering separate assembly problem and find new task time for each task (B) Minimize the number of workers using all the above developed mathematical constraints. While solving part B use the new tasks time obtained in part A.

5. COMPUTATIONAL RESULT

In this part, computational results are discussed. The case study are done using LINGO16.0 a mathematical programming software. For this 0-1 integer-programming model is developed using LINGO 16.0 with Intel core i5, 3.20 GHz processor and 4GB of RAM. LINGO used branch and bound algorithm to solve the problem.

TABLE 2: Solution of part A and part B

Sections	Major Tasks	Sub-tasks	Number of workers	Total no. of workers in each frame	Task time (sec)
Frame section	A	44	23	38	173
	B*	31	15		190
Stand -I	C	57	10	50	141
	D	4	3		240
	E	17	7		210
	F	3	2		167
	G*	13	4		108
	H	5	3		198
	I	4	12		187.5
	J	7	4		120
	K	5	4		80
	L	5	1		204
Stand -II	M	6	5	33	146
	N	7	5		95
	O*	5	3		75
	P	5	3		150
	Q*	7	6		53

Sections	Major Tasks	Sub-tasks	Number of workers	Total no. of workers in each frame	Task time (sec)
	R	7	5		80
	S	9	4		165
	T	3	2		23
Stand-III	U	12	10	33	120
	V	4	4		135
	W	4	2		152
	X	8	6		150
	Y*	11	11		120
	Total	283		154	
	*Sub-assembly				

As shown in Table 2. Increased number of workers on some stations does not affect the overall performance of assembly line. This is because at last total number of workers are reduced to an optimum amount. In established assembly line the number of workers, working is 186 and in modified assembly line, the number of workers are reduced to 154. The sub-tasks are increased to 283 from 254.

6. CONCLUSION AND FUTURE WORK

A case study of assembly line is proposed in this paper with 25 workstations with 25 sets of workers. Each sets of tasks contains different sub-tasks. Initially total number of workers working on line is 186 which is reduced to 154 after solving the problem. There are reduction of 17% of workers on assembly line. This will increase the space utilization beside the assembly line. Extra workers working on line can be used for others work in other sector of plant. This will also reduced the cost of production. The above result will also attract many company to apply the published research work as per their requirement.

This work may be extended for modification of whole assembly line by reducing the number of workstations and cycle time. Meta-heuristic method can be applied for comparative study of two different solution.

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Route Optimization of Fleet of Passenger Transport Vehicles using Bing MapsTM & Excel Solver: A Case Study

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Abstract: This paper presents a solution to real-life vehicle routing problem to an industry specific application with an objective to minimize the total transportation cost using Bing Maps & Excel solver. The expenditure that organizations have to incur for the daily commute of their employees contributes significantly to the company budget. This paper highlights the use of quantitative and analytical techniques to a real-life routing problem. A metaheuristic technique viz., large neighbourhood search (LNS) solves the problem using excel solver and macros, with sufficient number of iterations to gain accuracy. The output after sufficient iterations with the sequence of steps mentioned is used to create a path-to-follow that minimizes the total distance, thereby reducing the total cost of the transportation.

Keywords: Vehicle Routing Problem, Bing MapsTM, Excel Solver, Large Neighbourhood Search, Optimization.

1. INTRODUCTION

Transportation is an essential aspect of any logistics function and accounts to more than 1/3rd of total logistics costs. It may be of raw materials or finished goods, but transportation of employees can be prioritized above the rest as they are the ones who contribute the most to the operations in the company. This calls for creating a path-to-follow which covers all the pickup points from their destination. This forms the basis of vehicle routing problem, introduced by Dantzig and Ramser, 1959.

Vehicle Routing Problem (VRP) is one of the most commonly occurring optimization problems in the field of logistics. One such case of VRP is of transportation of employees from their homes every morning to the company and sending them back every evening with buses. This adds to overheads costs of the company, so it is important to reduce the cost of transportation by finding a path-to-follow which would have the minimum total distance amongst all possible ways. This version of the problem addresses the following considerations:

1. Limited homogeneous fleet of vehicles: the company owns a fleet composed of identical vehicle types;
2. Possibility of vehicles performing multiple trips;
3. For each vehicle, transportation cost per km.

The goal is to minimize the total cost composed of

- i. A fixed cost for using each vehicle,
- ii. A fixed cost per customer visited, and

- iii. A variable vehicle-dependent cost per distance travelled.

Besides minimizing total distribution costs, for managerial reasons the company is also concerned about three other routing indicators, namely,

- i. Minimize total number of routes employed,
- ii. Minimize total distance travelled, and
- iii. Minimize vehicles' idle capacity.

2. VRP SPREADSHEET SOLVER BY MR. GÜNEŞ ERDOĞAN

Mr. Güneş Erdoğan noticed the need for a standard tool that can be used to solve vehicle routing problems easily. He realized that it is indeed possible to construct a standard tool for representing, solving, and visualizing the results of VRPs on the computer. The resulting open-source Excel workbook named VRP Spreadsheet Solver and its user's manual are available for free download at <http://verolog.deis.unibo.it/vrp-spreadsheet-solver>.

This workbook utilizes Bing Maps web service to retrieve coordinate and distance data, and uses a Large Neighbourhood Search algorithm (proposed by P.Shaw in 1997) to provide solutions. It can solve Vehicle Routing Problems with up to 200 customers. VRP Spreadsheet Solver has been used on four continents by multiple small and medium enterprises, and the beneficiaries have reported cost savings of 10% to 20%.

3. THE PROBLEM STATEMENT

This company is situated at Chakan, and the objective of this paper is to find the optimal number of buses and minimize distances travelled from the workplace. The employee data of 317 employees had been recorded to include:

- Name of employee
- Work in the company
- Bus Stop
- Bus Route

The company wanted a vehicle routing solution such that they required the least number of buses to pick up their employees. Employees were given a survey where on the basis of the above four parameters, their responses were recorded. The procedure to go about this problem includes:

- i. Mapping Locations of company and bus stops.
- ii. Calculating Distance to and from each location.
- iii. Decide number of vehicles that are going to be plying.
- iv. Find a solution by deciding which route can be followed.
- v. Populate this on a map if possible for direct use and analysis.

3.1 Constraints in VRPs:

1: Depots – These depots may be located at multiple places throughout the city and hence this factor is also a variable, unless of course in a particular scenario you are given the data that has only one particular depot. The company is considered as a depot.

2: Vehicles – Vehicles form the basis of the problem since it is their routes that we set out to determine in the most optimal manner possible. It is essential also to take into account that these vehicles have maximum times of plying, and down times where they may be at rest or requiring maintenance. All this has to be factored when setting a time frame for the vehicles in the vehicle routing problems. The

company has a homogenous fleet of vehicles having equal seating capacity.

3: Customers – The employees in this case account for the major factor that determines the number of entities that are being plied, or are plied to. In case of a customer or their goods, there can also be variable quantities of goods that are being transported. It is possible that multiple employees can board/unboard at a given bus stop.

4. METHODOLOGY

The methodology that is followed here can be assigned in stages of work. These stages or steps are listed below along with their respective results. The heuristic algorithm that has been used in this research is Large Neighbourhood Search (LNS) metaheuristic which was proposed by Shaw. Most neighbourhood search algorithms explicitly define the neighbourhood. In the LNS metaheuristic, the neighbourhood is defined implicitly by destroy and repair method. A destroy method destructs part of the current solution while a repair method rebuilds the destroyed solution. The destroy method typically contains an element of stochasticity such that different parts of the solution are destroyed in every invocation of the method. The neighbourhood $N(x)$ of a solution x is then defined as the set of solutions that can be reached by first applying the destroy method and then the repair method. Here there are N identical vehicles of capacity C and M customers.

4.1 Location

The first step in the VRP Spreadsheet Excel solver is to secure a Bing Maps key to use the Macro that has been enabled in Excel. The first excel sheet seeks details of company and bus stops along with the number of passengers boarding/unboarding, option of pickup and delivery, average estimated vehicle speed, location of nodes, time windows etc. All information is compiled in the first excel worksheet shown in Table I.

TABLE 1: Location population sheet (Captures Latitudes and Longitudes of Company & Bus Stops)

Location ID	Name	Address	Latitude (y)	Longitude (x)	Time window start	Time window end	Must be visited?	Service time	Demand	Profit
0	Depot	Kalyani Forge, India	23.4060116	79.4580917	00:00	23:59	Starting location	0:00	0	0
1	Customer 1	Bhosari, India	18.6267605	73.8352890	00:00	23:59	Must be visited	0:00	0	0
2	Customer 2	Hadapsar, India	18.4995308	73.9396896	00:00	23:59	Must be visited	0:00	0	0
3	Customer 3	Bagban Nagar, India	21.1076202	79.0953522	00:00	23:59	Must be visited	0:00	0	0
4	Customer 4	Perne Phata, India	30.5863705	79.0348892	00:00	23:59	Must be visited	0:00	0	0
5	Customer 5	Shikrapur, India	18.6876411	74.1256714	00:00	23:59	Must be visited	0:00	0	0
6	Customer 6	Chas, India	23.6359901	86.1719818	00:00	23:59	Must be visited	0:00	0	0
7	Customer 7	Bajrangwadi, India	18.5108891	75.0808411	00:00	23:59	Must be visited	0:00	0	0
8	Customer 8	Maltan Phata, India	30.1860600	71.4479065	00:00	23:59	Must be visited	0:00	0	0
9	Customer 9	Shikrapur, India	18.6876411	74.1256714	00:00	23:59	Must be visited	0:00	0	0
10	Customer 10	Ksb Chowk Bus Stop, India	23.4060116	79.4580917	00:00	23:59	Must be visited	0:00	0	0
11	Customer 11	Koregaon Bhima, India	18.6455593	74.0591736	00:00	23:59	Must be visited	0:00	0	0
12	Customer 12	Koregaon Bhima, India	18.6455593	74.0591736	00:00	23:59	Must be visited	0:00	0	0
13	Customer 13	Joshiwadi, India	19.0292091	72.8428421	00:00	23:59	Must be visited	0:00	0	0
14	Customer 14	Chafekar Chowk Bus Stop, India	23.4060116	79.4580917	00:00	23:59	Must be visited	0:00	0	0
15	Customer 15	Hadapsar, India	18.4995308	73.9396896	00:00	23:59	Must be visited	0:00	0	0
16	Customer 16	Joshiwadi, India	19.0292091	72.8428421	00:00	23:59	Must be visited	0:00	0	0
17	Customer 17	Ahmednagar, India	19.0920792	74.7383194	00:00	23:59	Must be visited	0:00	0	0
18	Customer 18	Chakan, India	18.7547798	73.8602829	00:00	23:59	Must be visited	0:00	0	0
19	Customer 19	Mundhawa, India	18.5229340	73.9201126	00:00	23:59	Must be visited	0:00	0	0
20	Customer 20	Shel Pimpalgaon, India	21.6438198	74.0207672	00:00	23:59	Must be visited	0:00	0	0

4.2 Setup Distances Sheet

The distance of the company and bus stops is calculated from the first excel sheet and a second distances sheet is populated by the solver. Furthermore, the duration from the depot to the destined location is also calculated. To improve the accuracy in the duration calculation, it is recommended that time input is given with a specific window in the start of the use of this macro.

The blank distance sheet looks like the one shown in table II and a populated distance sheet specifying the distances between various nodes (company and bus stops) is generated by solver as shown in table III.

TABLE 2: Distances worksheet generated by solver

	A	B	C	D
1	From	To	Distance	Duration
2	Depot	Depot	0.00	0:00
3	Depot	Customer 1	0.00	0:00
4	Depot	Customer 2	0.00	0:00
5	Depot	Customer 3	0.00	0:00
6	Depot	Customer 4	0.00	0:00
7	Depot	Customer 5	0.00	0:00
8	Depot	Customer 6	0.00	0:00
9	Depot	Customer 7	0.00	0:00
10	Depot	Customer 8	0.00	0:00
11	Depot	Customer 9	0.00	0:00
12	Depot	Customer 10	0.00	0:00
13	Depot	Customer 11	0.00	0:00
14	Depot	Customer 12	0.00	0:00
15	Depot	Customer 13	0.00	0:00
16	Depot	Customer 14	0.00	0:00
17	Depot	Customer 15	0.00	0:00
18	Depot	Customer 16	0.00	0:00
19	Depot	Customer 17	0.00	0:00
20	Depot	Customer 18	0.00	0:00
21	Depot	Customer 19	0.00	0:00
22	Depot	Customer 20	0.00	0:00
23	Depot	Customer 21	0.00	0:00

TABLE 3: Distances worksheet populated by solver

From	To	Distance	Duration
Depot	Depot	0.00	0:00
Depot	Customer 1	8.84	0:21
Depot	Customer 2	0.00	0:00
Depot	Customer 3	0.00	0:00
Depot	Customer 4	29.40	0:33
Depot	Customer 5	18.19	0:34
Depot	Customer 6	0.00	0:00
Depot	Customer 7	4.54	0:13
Depot	Customer 8	20.77	0:25
Depot	Customer 9	148.57	3:09
Depot	Customer 10	10.00	0:16
Depot	Customer 11	26.68	0:33
Depot	Customer 12	8.28	0:29
Depot	Customer 13	0.00	0:00
Depot	Customer 14	29.40	0:33
Depot	Customer 15	4.54	0:13
Depot	Customer 16	8.84	0:21
Depot	Customer 17	5.85	0:14
Depot	Customer 18	29.40	0:33
Depot	Customer 19	0.00	0:00
Depot	Customer 20	8.28	0:29
Depot	Customer 21	0.00	0:00

4.3 Setup Vehicles Sheet

The third sheet generated seeks information related to vehicles such as vehicle type, name, capacity, fixed cost per trip, cost per unit distance, available number of vehicles as shown in tables IV & V.

TABLE 4: Vehicle Parameters sheet as generated by the solver

A	B	C	D	E	F
Vehicle type ID	Type name	Capacity	Fixed cost per trip	Cost per unit distance	Number available
1	A	1	0	1	1

TABLE 5: Vehicle Parameters sheet as modified to suit case study parameters

A	B	C	D	E	F
Vehicle type ID	Type name	Capacity	Fixed cost per trip	Cost per unit distance	Number available
1	A	30	0	1	4

4.4 Solutions, Solver and Visualization

On successful entry of all information in the first three excel sheets, the solver validates it and generates solutions worksheets as shown in tables VI & VII. The said solution is generated on bing maps automatically showing the pictorial path of each individual vehicle route as shown in figure 1.

As shown in tables VI & VII, the solutions worksheet specifies all vehicles and route both on the excel solutions sheet as well as bing maps. It includes the vehicles used, number of nodes (bus stops) served, the optimized route formed indicating the sequence of nodes, distance travelled between all consecutive nodes on each route, vehicle arrival and departure time at each node, waiting times, if any. This takes into consideration a majority of practical aspects making this approach valid and useful in solving real life vehicle routing problems. To increase the specificity and the accuracy, it is essential to input parameters that are closest to the actual scenario.

TABLE 6: Solutions worksheet for Route 2 (Bus 2)

N	O	S	T	V	W	X	Y
Vehicle:	A 2	Stops:	12	Net profit:	-4.54		
Stop count	Location name	Distance	Delivered	Driving time	Arrival	Departure	Working time
0	Depot	0.00	0	0:00	07:00	07:00	0:00
1	Customer 7	4.54	0	0:13	07:13	07:13	0:13
2	Customer 15	4.54	0	0:13	07:13	07:13	0:13
3	Customer 23	4.54	0	0:13	07:13	07:13	0:13
4	Customer 26	4.54	0	0:13	07:13	07:13	0:13
5	Customer 31	4.54	0	0:13	07:13	07:13	0:13
6	Customer 39	4.54	0	0:13	07:13	07:13	0:13
7	Customer 45	4.54	0	0:13	07:13	07:13	0:13
8	Customer 63	4.54	0	0:13	07:13	07:13	0:13
9	Customer 77	4.54	0	0:13	07:13	07:13	0:13
10	Customer 87	4.54	0	0:13	07:13	07:13	0:13
11	Customer 98	4.54	0	0:13	07:13	07:13	0:13
12	Customer 8	4.54	0	0:13	07:13	07:13	0:13

TABLE 7: Solutions Worksheet for Route 3 (Bus 3)

AA	AB	AF	AG	AI	AJ	AK	AL
Vehicle:	A 3	Stops:	20	Net profit:	-53.73		
Stop count	Location name	Distance	Delivered	Driving time	Arrival	Departure	Working time
0	Depot	0.00	0	0:00	07:00	07:00	0:00
1	Customer 37	53.73	0	1:32	08:32	08:32	1:32
2	Customer 52	53.73	0	1:32	08:32	08:32	1:32
3	Customer 54	53.73	0	1:32	08:32	08:32	1:32
4	Customer 59	53.73	0	1:32	08:32	08:32	1:32
5	Customer 65	53.73	0	1:32	08:32	08:32	1:32
6	Customer 72	53.73	0	1:32	08:32	08:32	1:32
7	Customer 82	53.73	0	1:32	08:32	08:32	1:32
8	Customer 94	53.73	0	1:32	08:32	08:32	1:32
9	Customer 11	53.73	0	1:32	08:32	08:32	1:32
10	Customer 41	53.73	0	1:32	08:32	08:32	1:32
11	Customer 28	53.73	0	1:32	08:32	08:32	1:32
12	Customer 41	53.73	0	1:32	08:32	08:32	1:32
13	Customer 50	53.73	0	1:32	08:32	08:32	1:32
14	Customer 57	53.73	0	1:32	08:32	08:32	1:32
15	Customer 66	53.73	0	1:32	08:32	08:32	1:32
16	Customer 60	53.73	0	1:32	08:32	08:32	1:32
17	Customer 68	53.73	0	1:32	08:32	08:32	1:32
18	Customer 74	53.73	0	1:32	08:32	08:32	1:32
19	Customer 52	53.73	0	1:32	08:32	08:32	1:32
20	Customer 97	53.73	0	1:32	08:32	08:32	1:32

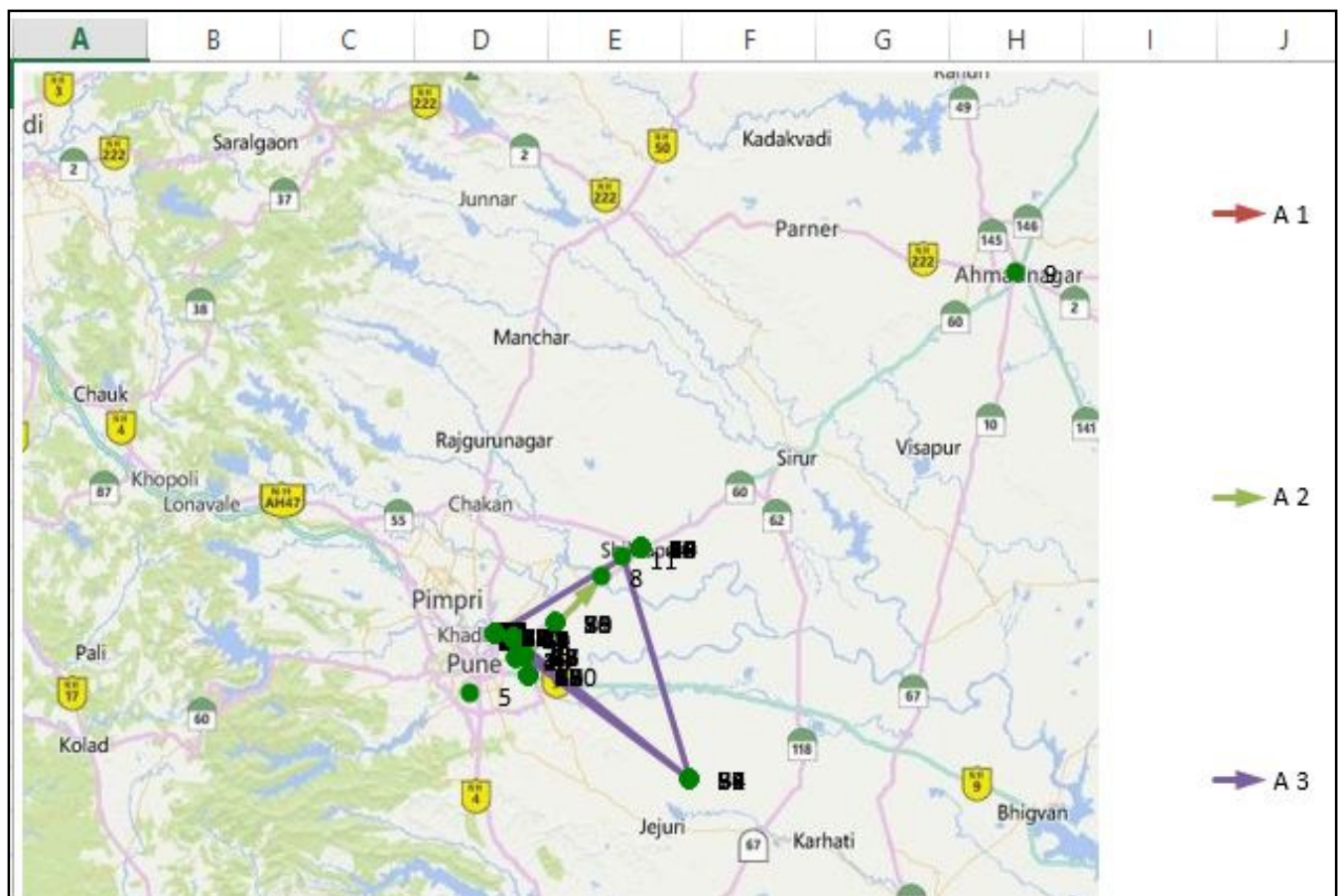


Fig. 1. Bing Maps solution showing the routes obtained for case study

5. CONCLUSION

Solving a vehicle routing problem effectively is not easy, let alone the usage of softwares to solve it. It can be seen that some softwares do exist that provide alternative algorithms that solve such VRPs. Most simplest and workable of all is the VRP Spreadsheet Solver macro, an effective tool to use for companies that are small scale and upwards. It is open-source and hence is free to use upon downloading. Constraints can be input as per the need into the solver and it will give a solution (upto 200 entities). However, it does not account for real time traffic data, and hence you may arrive at a route whose feasibility should be checked with a map. That being said, the solution that the

VRP Spreadsheet Solver macro for Excel provides is essentially much easier to obtain than a normal vehicle routing problem that may have plenty of variables.

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SECTION – IV
PLANT LAYOUT AND LOCATION

Flexible Bay Dynamic Facility Layout Problems using Aisle Structure

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Abstract: Dynamic facility layout problem (FLP) is the task of locating the positions of the facilities/departments on available floor space for certain planning horizons that provide minimum material handling cost. The design of facility layout is incomplete without consideration of aisle structure for material handling and personnel travelling. This paper presents a method to solve dynamic FLP with flexible bay structure (FBS) having aisles or passages. In FBS, the facilities are arranged in horizontal or vertical bays of varying width. In first stage, the dynamic FLP with FBS are solved using biogeography-based optimization (BBO) algorithm and in second stage an aisle structure is developed for material and personnel flow.

Keywords: Dynamic facility layout problem, flexible bay structure, aisle construction, biogeography-based optimization

1. INTRODUCTION

In present manufacturing environment, the product demands are volatile in nature. Therefore the facility layout should be flexible to changing demands which is called as dynamic facility layout. In dynamic layout, the arrangement of facilities/departments for one planning period should be easily reconfigurable for next planning period with minimum cost. In this paper, we are considering dynamic, unequal-area FLPs with flexible bay structure. In most of the real industries the facilities are unequal in shape; therefore in this paper main focus is given on the unequal area FLPs. Dynamic FLPs are addressed by many of the researchers; however their study is limited to equal area dynamic FLPs while very few researchers studied unequal area dynamic FLPs. In previous literature, very few researchers considered aisles while solving a FLP. However, while designing any layout, aisles or passages are integral part of the layout for smooth and suitable flow of material and workers. Therefore in this paper, a new structure of aisles is developed for unequal area facility layout with flexible bay structure (FBS). Till date, dynamic FLPs having FBS are attempted by a researcher with only 12 departments which is considered as small size FLP. Therefore, a pseudo problem is generated randomly having 20 departments with two planning periods. In first stage, the dynamic FLP of 20 departments is solved using one of the most efficient metaheuristic method i.e. BBO algorithm to obtain best solution and in second stage, a potential aisle structure is explained for proper material flow.

2. LITERATURE REVIEW

The extensive literature reviews were carried out for dynamic FLPs and FLPs considering aisles. The literature review is categorised as below:

2.1 Dynamic FLP

The first study on dynamic facility/plant layout is done by Rosenblatt (1986). The multi-period FLP is modelled using dynamic programming and solved using a heuristic method. Balakrishnan et al. (2000) proposed two algorithms, namely dynamic programming and pair-wise exchange heuristic to solve dynamic FLP to minimize material handling cost and rearrangement cost of facilities during different planning periods. Balakrishnan et al. (2003) implemented hybrid genetic algorithm (HGA) to optimize 6, 15 and 30 department DFLP and compared with other algorithms. Dunker et al., (2005) presented an algorithm combining dynamic programming and genetic search for solving a DFLP with unequal areas. McKendall and Shang (2006) proposed hybrid ant systems to solve DFLP with 5 and 10 periods of planning horizon. Sahin and Turkbey (2009) presented a new hybrid heuristic based on the simulated annealing (SA) approach supplemented with a tabu list for the DFLP.

Emami and Nookabadi (2013) attempted DFLP with multi-objective function having equal area facilities and optimized using non-dominated sorting GA and Pareto-simulated annealing algorithm. Chen and Lo (2014) presented DFLP with multi-objective function and optimized using ACO. The industries such as footwear and clothing are prone to seasonal demand changes, thus, time horizons and layout/re-layout of the machines within the facility should be studied carefully (Ulutas and Islier, 2015). They considered a footwear facility layout and several scenarios are generated by using the real life data. A clonal selection based algorithm is proposed to solve the real life DFLP. Remanufacturing is a preparation of rising importance due to increasing environmental awareness and regulations (Li, et al. 2015). They presented an optimization

method for remanufacturing dynamic facility layout with variable process capacities, unequal processing cells, and inter-cell material handling.

2.2 FLP with aisles

Wu and Appleton (2002) presented a combined method to optimize the facility layout and aisle structure by SA. Slicing structure is used for layout design and the slicing lines on the floor are used as the aisle structure for the material handling. Gomez et al. (2003) applied GA to solve factory layout problems by considering passageways. Lee et al. (2005) explained the formulation for multi-floor, unequal area FLP with inner structure walls and passages and solved using improved GA. Ye and Zhou (2007) developed a new local GA hybridized tabu search, to solve multi-criteria FLPs by considering fixed aisles and transverse passageways between sections. Alagoz et al. (2008) introduced a method for finding useful aisle structures for a given flexible bay block layout.

3. MATHEMATICAL FORMULATION OF DYNAMIC FLP

The dynamic FLP having unequal area can be formulated as follows (McKendall and Hakobyan, 2010):

$$\text{Minimize } F = \sum_{t=1}^T \sum_{i=1}^N \sum_{j=1}^N f_{tij} d_{ij} c_{ij} + \sum_{t=2}^T \sum_{i=1}^N \sum_{j=1}^N A_{tij} Y_{tij} \quad (1)$$

$$MHC(s) = \sum_{i=1}^n \sum_{j=1}^n f_{ij} d_{ij} c_{ij} \quad (2)$$

$$\alpha_i = \frac{\max\{l_i, w_i\}}{\min\{l_i, w_i\}} \leq \alpha_{max} \quad (3)$$

$$l_i^{min} = \min\{l_i, w_i\} \quad (4)$$

$$P_c(s) = (n_s)^k \times MHC(s) \quad (5)$$

Where

F - Total material handling and rearrangement cost

N - Number of departments or the locations

T - Number of periods

f_{tij} - Material flow in period t between department i to department j

d_{ij} - Rectilinear distance between the centroids of locations j and i

c_{ij} - Unit cost between department i and j

A_{tij} - Fixed cost of moving department i to j at period t

Y_{tij} - 0, 1 variable for shifting facility i to j in period t

$MHC(s)$ - Material handling cost of layout s in period t ,

α_i - Aspect ratio of facility i ,

α_{max} - Maximum allowable aspect ratio,

l_i^{min} - Minimum side length of facility i ,

$P_c(s)$ - Penalty function for infeasible facilities in layout s ,

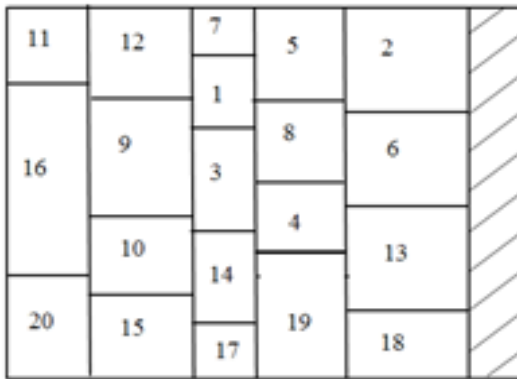
n_s - Number of infeasible facilities in layout s ,

k - Severity parameter of the penalty function

The value of k is decided by layout problem solver (Ulutas and Kulturel-Konak, 2012). If the minimum side length of facility is less than l_{min} then the facility is infeasible.

3.1 Construction of aisle structure

Assuming that the optimal layout is obtained which is shown in Fig. 1 (a). The facilities are arranged in flexible vertical bays, starting from top left corner in downward direction. The shaded space on the right side of the layout will be accommodated by the aisles. The facilities will shift to right side, when the aisles are designed.



(a)



(b)

Fig. 1(a) 20-department layout (b) Layout with aisles

In the layout, it is assumed that four aisles shown as coloured in Fig. 1(b) are necessary which are defined as follows (Alagoz et al., 2008):

- 1) The right-hand side of the first bay
- 2) The left-hand side of the last bay
- 3) Top horizontal line between first and last bay4)
Bottom horizontal line between first and last bay

These four aisles are considered because they are convenient, long and vertical which are suitable for material handling equipment and travelling of persons.

Furthermore, we need possible aisles to travel from second and second last bay. Both the right-hand and left-hand side of the bays between the first and last bays are considered as fixed aisles as shown in Fig. 1(b). Further, for convenience of material handling, short horizontal aisles between the facilities are considered. From Fig. 1(b), it is clear that, the upper boundary of facilities 10, 14 and 19 is almost near to each other as compared to other facilities. Therefore, these three aisles are considered as horizontal aisles in the layout. Finally, the total number of aisles in the layout is nine; four vertical and five horizontal. The width of the aisle is fixed and it is decided according to the size of material handling equipment. The area of the layout should be large enough to accommodate the aisles.

4. BIOGEOGRAPHY BASED OPTIMIZATION ALGORITHM (BBO)

BBO algorithm comes under the category of population-based evolutionary algorithms and it is developed by Simon in 2008. BBO is based on concept of island biogeography in which topographical distribution of living species is explained (Alroomi et al., 2013). The working procedure of

BBO is developed by considering the migration of species from one island to another. On an island or habitat, if the conditions of living are well suited for species then that habitat have high suitability index (HSI), because this habitat have better features than other habitats. The habitability is illustrated as suitability index variables (SIVs). Habitats with high HSI have more number of species as compared to low HSI habitats. Therefore, the species on the high HSI habitats can emigrate to other habitat and have low species immigration rate as the population of species is high. Similarly, the low HSI habitats have high species immigration rate as there is very low population.

5. APPLICATION OF BBO ALGORITHM TO 20-DEPARTMENT DYNAMIC FLP

The 20 department FLP is generated for two periods of planning horizon. The specifications are given below:

Number of departments = 20; Length of layout (L) = 18; Width of layout (W) = 24;

Area of total layout = $L*W = 18*24 = 432$; Aspect ratio (α_{max}) = 5; Number of time periods (T) = 2;

Rearrangement or shifting cost (R_{it}) = 10 (for all departments);

Areas of the departments = {19, 16, 29, 19, 13, 29, 30, 19, 12, 15, 18, 22, 15, 22, 24, 14, 12, 16, 16, 18}

5.1 Results of 20 department FLP using BBO

The material flow data for first and second period is shown in Table 1 and 2 respectively. The results are shown in Table 3.

TABLE 1 : Material flow for first period

f_{ij}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	36	49	1	2	26	11	31	25	29	46	8	14	27	40	4	11	45	24	30
2	-	0	47	39	7	6	18	5	47	41	33	6	28	45	27	49	48	2	23	13
3	-	-	0	27	34	10	47	3	50	44	24	49	0	34	2	12	23	10	24	22
4	-	-	-	0	4	10	45	39	12	20	50	26	11	18	6	16	13	44	43	23
5	-	-	-	-	0	37	5	45	44	42	41	3	21	28	2	36	33	21	44	19
6	-	-	-	-	-	0	34	0	45	4	0	12	34	31	25	41	44	20	12	13
7	-	-	-	-	-	-	0	9	5	16	4	33	31	38	2	17	31	44	47	32
8	-	-	-	-	-	-	-	0	48	21	47	16	46	15	20	3	34	4	7	7
9	-	-	-	-	-	-	-	-	0	40	43	24	40	11	43	4	35	4	11	4
10	-	-	-	-	-	-	-	-	-	0	41	31	38	15	10	16	20	24	7	38
11	-	-	-	-	-	-	-	-	-	-	0	34	12	10	33	7	18	37	6	48
12	-	-	-	-	-	-	-	-	-	-	-	0	35	44	42	27	22	16	10	48
13	-	-	-	-	-	-	-	-	-	-	-	-	0	42	19	3	21	4	31	15
14	-	-	-	-	-	-	-	-	-	-	-	-	-	0	29	1	2	28	32	43
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	45	25	7	35	39
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	25	37	48	0
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	31	38	20
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	7	17
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

TABLE 2: Material flow for second period

f_{ij}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	11	33	8	4	10	49	11	36	21	28	48	27	19	14	12	40	3	36	42
2	-	0	42	39	47	0	22	14	22	50	45	40	50	35	2	3	28	31	35	25
3	-	-	0	22	24	45	2	7	31	47	20	23	12	6	15	50	4	38	1	40
4	-	-	-	0	31	13	27	36	6	30	22	32	30	6	18	14	49	6	40	13
5	-	-	-	-	0	30	22	50	26	33	3	22	13	45	15	35	44	17	45	27
6	-	-	-	-	-	0	0	2	35	24	17	18	11	36	41	0	15	44	46	23
7	-	-	-	-	-	-	0	26	40	6	11	31	35	48	41	48	11	15	40	6
8	-	-	-	-	-	-	-	0	19	33	14	30	32	26	27	31	12	35	28	48
9	-	-	-	-	-	-	-	-	0	46	36	44	36	17	32	42	6	28	14	45
10	-	-	-	-	-	-	-	-	-	0	3	7	16	25	47	23	28	21	37	31
11	-	-	-	-	-	-	-	-	-	-	0	23	30	30	31	9	17	5	30	48
12	-	-	-	-	-	-	-	-	-	-	-	0	47	45	35	44	12	0	28	46
13	-	-	-	-	-	-	-	-	-	-	-	-	0	21	23	20	21	0	32	1
14	-	-	-	-	-	-	-	-	-	-	-	-	-	0	5	36	32	6	27	49
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	40	16	32	24	17
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	30	15	26	49
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	12	34	48
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	37	28
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	44
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

TABLE 3: Results of 20-department dynamic FLP

Trials	Total layout cost	Computational time
1	116173	90.12
2	115545	92.34
3	117857	89.13
4	114834	90.55
5	119248	93.08
6	118371	94.11
7	116203	89.60
8	118372	91.89
9	119055	92.13
10	120663	89.03
Average	117630	91.19

Table 3 shows the total layout cost for both the planning periods using BBO. The algorithm runs for 10 trials to see the performance of BBO on dynamic FLP. It is observed that in every trial, the value of total layout cost obtained is not much different than the best value. The computational time required for one trial of BBO algorithm is shown in seconds. The average of total layout cost and time is calculated to show the deviation from the best values. The best layouts for first and second planning period are shown in Fig. 2.

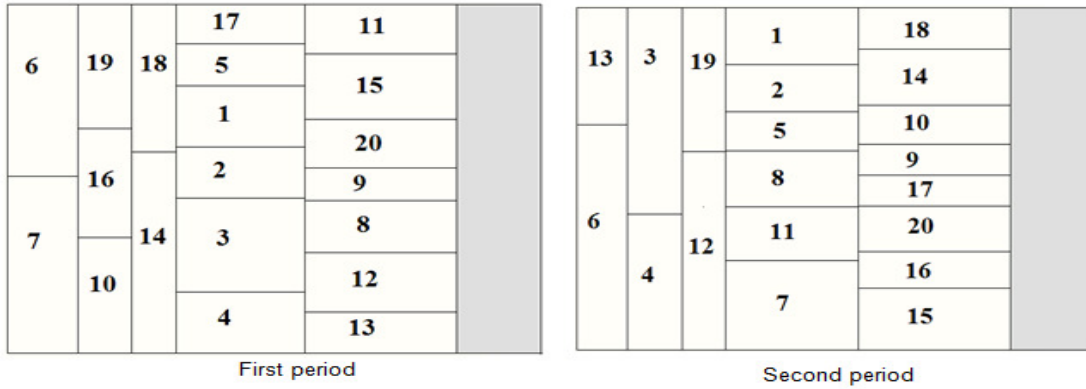


Fig. 2. Best layouts of 20-department dynamic FLP

5.2 Aisle construction for 20-department dynamic FLP

The possible aisle structures for first and second planning periods are shown in Fig. 4. In Fig. 3, it is seen that the space in right side is blank. This space will be utilised to design the aisles. As discussed in section 3.2, the aisles are constructed on the boundaries of bays. After allotting space for aisles, the areas of the departments will be reduced this will cause infeasible departments. As shown in Fig. 4, after construction of first aisle on the right boundary of first bay, the departments on the right side of first bay will be shifted to right side by the amount of length equal to the width of the first aisle. In this manner, all the aisles are constructed. The aisle width is decided according to the width of the material handling equipment.

In Fig. 4, it is seen that there are total seven aisles, four vertical and five horizontal. The upper boundaries of departments 16, 14 and 2 are nearly on same height; hence these two aisles are possible aisles. After positioning these aisles, the total layout area is utilised. In Fig. 4, departments 19, 16, 10, 18, 14, 17, 5, 1, 2, 3, and 4 will reduce in area, because aisle structure consists of these departments only. The utilisation of blank space in the layout is described below:

Number of vertical aisles = 4; Number of horizontal aisles = 3

Number of vertical bays or rows = 5; Widths of the bays = {3.28, 2.5, 2.11, 6.0, 7.11}

String of the departments = 6-7-19-16-10-18-14-17-5-1-2-3-4-11-15-20-9-8-12-13

Lengths of the departments = $\{l_6, l_7, l_{19}, l_{16}, l_{10}, l_{18}, l_{14}, l_{17}, l_5, l_1, l_2, l_3, l_4, l_{11}, l_{15}, l_{20}, l_9, l_8, l_{12}, l_{13}\}$
 $= \{8.85, 9.15, 6.4, 5.6, 6.0, 7.58, 10.42, 2.0, 2.17, 3.17, 2.67, 4.83, 3.17, 2.53, 3.37, 2.53, 1.68, 2.67, 3.09, 2.11\}$

Widths of the departments = $\{w_6, w_7, w_{19}, w_{16}, w_{10}, w_{18}, w_{14}, w_{17}, w_5, w_1, w_2, w_3, w_4, w_{11}, w_{15}, w_{20}, w_9, w_8, w_{12}, w_{13}\}$
 $= \{3.28, 3.28, 2.5, 2.5, 2.5, 2.11, 2.11, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 7.11, 7.11, 7.11, 7.11, 7.11, 7.11, 7.11\}$

Total area of layout = 432; Total area of all the departments = 377.83

Blank area = (Total area of layout - Total area of all the departments) = 54.17

Length of blank area = 18; Width of blank area = 3; Width of aisle = 0.2

Total width of vertical aisles = $4 \times 0.2 = 0.8$

Width of blank area after placing aisles

$= (\text{Width of blank area} - \text{Total width of vertical aisles}) = (3 - 0.8) = 2.2$

From above discussion, it is clear that the widths of the bays and departments are adjusted satisfactorily by shifting to right side. Now, the lengths of the departments will also reduce due to horizontal aisles.

Total width of horizontal aisles in 2nd bay = $3 \times 0.2 = 0.6$

Total width of horizontal aisles in 3rd bay = $3 \times 0.2 = 0.6$

Total width of horizontal aisles in 4th bay = $3 \times 0.2 = 0.6$

As, there are three departments in 2nd bay, hence the lengths of the departments 19, 16 and 10 will reduce by 0.2 units each. The length reduction will be uniform throughout the bay. In 3rd bay, the lengths of departments 18 and 14 will be reduced by 0.3 units each. In 4th bay, there 6 departments, therefore the length of departments 17, 5, 1, 2, 3 and 4 will be reduced by 0.1 unit each. New lengths of departments will be calculated by subtracting the reduction from original length (new $l = l - \text{reduction}$) as follows:

{6.2, 5.4, 5.8, 7.28, 10.12, 1.9, 2.07, 3.07, 2.57, 4.73, 3.07}

After calculating the reduced lengths of the departments, the feasibility of the departments are to be checked using the constraint of maximum allowable aspect ratio of the departments which is $\alpha_{max} = 5$. Aspect ratio can be calculated by dividing the larger side of the department to shorter side. New calculated aspect ratios are as follows:

{2.48, 2.16, 2.32, 3.45, 4.79, 3.15, 2.89, 1.95, 2.33, 1.27, 1.95}

The aspect ratios of all the above departments are within the limit. So, these departments are feasible. The area reduction of the department due to reduced lengths is:

Total area reduction of the departments = 3.6

*Total area of vertical aisles = no. of vertical aisles * (width of aisles*length of aisles)*

*= 4 * (0.2 * 18) = 14.4*

Total area required by aisles = (Total area reduction of the departments+ Total area of vertical aisles)

= 3.6 + 14.4=18

The area of blank space is 54.17, which is more than the total area required by aisles. Therefore, the design structure of aisles can be successfully implemented on unequal area FLP with FBS.

Fig. 3 shows the aisle structure for second period, respectively. In second planning period, there are five horizontal aisles and four vertical aisles.

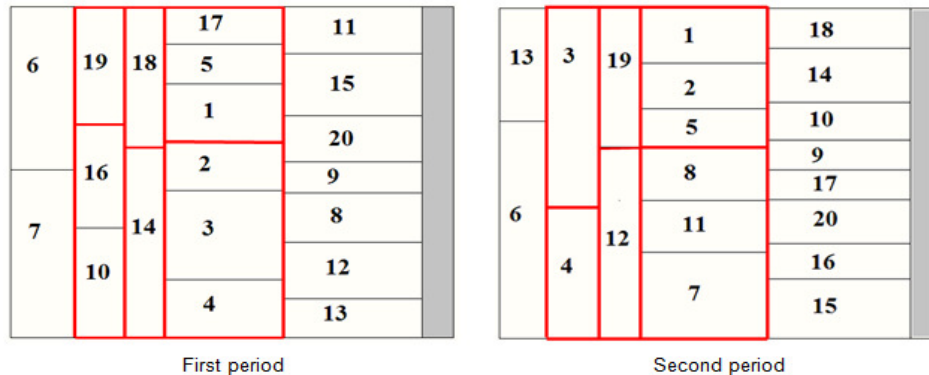


Fig. 3. Best layouts with aisles

As the number of aisles increases, the aisle construction cost and total layout cost will also increase. In this paper, the aisle construction cost is not considered, but from above construction design the layout planner can get idea of the cost of aisle construction, which will be beneficial for layout design.

6. CONCLUSION

Today's manufacturing industry is changing very fast; it means that the layouts are not static for longer period of time. The market is dynamic in nature, therefore while designing the layout, several time periods should be considered and the rearrangement cost is calculated. In many research articles, aisles or passages are not considered for material flow. This can lead to poor layout solutions. To avoid this drawback, an aisle construction procedure is described. The presented aisle structure is implemented on a randomly generated dynamic FLP of 20 departments with two planning horizons. The problem is solved using flexible bay structure and optimized using BBO. After obtaining the optimal layouts for all planning periods, the possible aisle structure is described which is easy to understand and flexible to design for convenient material flow.

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Facility Layout Problem Using Firefly and Biogeography-Based Optimization Algorithms

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Abstract: *Appropriate floor space optimization is referred as facility layout problem (FLP). Various FLPs are studied by researchers in all the fields of engineering. Theoretical work published by previous researchers on FLP has less relevance to real life problems of facility layouts. Therefore, an industrial case-study is carried out in plastic manufacturing company and presented in this paper. The FLP of the industrial case-study is formulated to minimize total material handling cost. Two metaheuristic techniques namely firefly algorithm (FA) and biogeography-based optimization (BBO) algorithm are applied to obtain the optimized solutions for the FLP of the considered case-study. Both the algorithms are providing better results than the original layout cost, however the solution quality of BBO is better than FA.*

Keywords: *Facility layout problem, unequal area facilities, firefly algorithm, biogeography-based optimization*

1. INTRODUCTION

The major goal of a manufacturing industry is facility layout design which is a necessary foundation and can be called as facility layout problem (FLP). An appropriated planning of facility layout includes many aspects such as material to be handled, machines, material handling equipment, ventilation, passageways employees/workers to construct the efficient layout. Facility layouts are classified as equal area facility layout, unequal area facility layout, single row facility layout, multi-floor facility layout. In actual practise, the layout planner is encountered with unequal area FLP, therefore the same is considered in this paper for a real case-study in an industry. The FLP formulation is quadratic assignment programming (QAP) with the objective of minimization of total material handling cost.

In previous literature, less attention is given on real case-studies of manufacturing industries and hence it is difficult to connect the solutions obtained for benchmark problems in previous literature to the FLP of an industry. Therefore, in this paper it is attempted to solve FLP of plastic manufacturing company and the total material handling cost or layout cost is optimized using two efficient non-traditional optimization techniques i.e., firefly algorithm (FA) and biogeography-based optimization (BBO) algorithm. The results obtained using FA and BBO are better than the original layout cost; however BBO algorithm is outperforming FA in terms of solution quality.

2. LITERATURE REVIEW

The literature review focuses on the unequal area FLPs and the considered metaheuristic techniques FA and BBO. In 1992, Tam described unequal area FLP with slicing tree

structure with the constraints of aspect ratio and dead space ratio and he applied simulated annealing (SA) algorithm to obtain results. Kim and Kim (1995) proposed a graph theoretic heuristic, in which the initial layout was generated and get improved through a local search technique. Schnecke and Vornberger (1997) implemented hybrid genetic algorithm (HGA) to solve unequal area FLPs with tree structure. Later, Lee and Lee (2002) introduced a shape-based block layout (SBL) approach for solving fixed-shape unequal area FLPs using HGA. Scholz et al. (2009) approached both fixed and flexible shape FLPs using tabu search (TS) technique.

FA is well-known technique to solve various optimisation problems. An application of FA for single row FLP is described by Sonmez and Baray (2013). Sayadi et al. (2010) presented discrete FA to solve permutation flow shop scheduling problems. Jati and Suyanto (2011) implemented FA to TSP.

Sayadi et al. (2013) applied FA to solve manufacturing cell formation problems. Ingole and Singh (2016) implemented FA to solve unequal area, fixed shape FLPs. It is observed that FA has wide domain of applications including combinatorial optimization problems. BBO is one of the most applicable techniques to obtain optimized solutions of problems. Rahmati and Zandieh (2012) developed the BBO algorithm for flexible job shop scheduling problem (FJSP). An application of BBO is described by Sooncharoen et al. (2015) for the machine layout design problems to minimize the material handling distance. Lim et al. (2016) proposed a hybrid technique combining BBO and TS to solve QAP and obtained better results within reasonable computational time.

3. MATHEMATICAL FORMULATION OF UNEQUAL AREA FLP

FLP having unequal shapes and size of facilities can be arranged as fixed shape or flexible shape. These FLPs are approached by some researchers; Schnecke and Vornberger (1997) and Scholz et al. (2009) used slicing tree structure and Lee and Lee (2002) used flexible bay structure. In this FLP, number (n) of facilities/departments of width w and length l are assigned on the floor layout space having total length (L) and width (W). The objective function for the FLP of industrial case-study is as follows:

$$\text{Minimize } F = \sum_{i=1}^n \sum_{j=1}^n f_{ij} d_{ij} c_{ij} \quad (1)$$

Subject to

$$d_{ij} = |x_i - x_j| + |y_i - y_j| \quad (2)$$

$$\sum_{u=1}^k l_u \leq 1.25 \sqrt{\sum_{v=1}^n A_v} \quad (3)$$

$$O_{ij} = \beta_{ij} (\lambda_{xij}) (\lambda_{yij}) \quad (4)$$

$$\lambda_{xij} = \left(\frac{l_i + l_j}{2} \right) - |x_i - x_j| \quad (5)$$

$$\lambda_{yij} = \left(\frac{w_i + w_j}{2} \right) - |y_i - y_j| \quad (6)$$

$$\beta_{ij} = \begin{cases} 0 & \text{for } \lambda_{xij} \leq 0 \text{ and } \lambda_{yij} \leq 0 \\ 1 & \text{otherwise} \end{cases}$$

F -Objective function to minimise the material handling cost (MHC)

i, j = facility index (1, 2, ..., n)

n = number of facilities/departments

c_{ij} = cost of one unit of material flow between facilities i and j

f_{ij} = amount of material flow between facilities i and j

d_{ij} = rectilinear distance between locations of facilities i and j

l_u = length of facility

A_v = area of facility

$u = 1, 2, \dots, k$ (facility index for number of departments in a bay)

$v = 1, 2, \dots, n$

O_{ij} Overlapping constraint

l_i and l_j are lengths of departments i and j

w_i and w_j are lengths of departments i and j

4. FIREFLY ALGORITHM (FA)

FA is a new optimization technique developed by Yang in 2010. It is inspired by the behaviour of attraction among the fireflies and deals with their variations of light intensity (Yang, 2010). The algorithm steps of FA are as follows:

Step 1: Randomly generate initial population of fireflies. Set the parameters such as number of fireflies, generations, absorption coefficient (γ), randomization parameter (α)

Step 2: Define objective function and evaluate intensity of light (i.e., fitness value) for all fireflies.

Step 3: According to the intensity value, select the best firefly.

Step 4: Calculate the distance of best firefly from other fireflies and update the positions of fireflies.

Step 5: Evaluate firefly intensities and rank the firefly intensities.

Step 6: Select the best firefly for the iterations.

Step 7: Update the fitness values and if the iterations reach the maximum generation limit, then stop else go to step 4.

5. BIOGEOGRAPHY-BASED OPTIMIZATION (BBO)

BBO algorithm is developed by Simon in 2008 which is a population-based evolutionary algorithm. BBO algorithm shares information from one island to other through migration and mutation. BBO algorithm is based on theory of island biogeography in which geographical distribution of biological species is explained (Alroomi et al., 2013). BBO algorithm follows migration and mutation operations to reach global minimum solution. The variables that describe habitability of an island are called as suitability index variables (SIVs) (Simon, 2008). Each island is considered as one solution. By considering the emigration (μ) and immigration (λ) rates of each member, the information between the habitats is shared probabilistically. BBO steps are as follows:

Step 1: Initialise BBO parameters i.e. number of islands or number of layouts (S), each island represents the permutation of facilities from $n = 1, 2, \dots, k$, generations of algorithm (G), maximum immigration rate (I), maximum emigration rate (E), maximum number of species on an island (S_{max})

Step 2: Evaluate the fitness function or objective function

Step 3: Calculate the values of μ and λ . Sort the values in descending order to map them according to emigration and immigration.

Step 4: Apply migration operator to modify the SIVs. The good features and information is shared between habitats or islands. This depends on emigration rates μ and immigration rates λ of each solution.

Step 5: Mutation is done to increase the diversity of the population members to obtain the good solutions.

Step 6: Clear any duplicated islands and evaluate the fitness function.

Step 7: Find the best minimum value. If the stopping criteria satisfied terminated the algorithm else go to step 4.

6. APPLICATION OF FA AND BBO ON FLP OF CASE-STUDY

This case-study is performed at Nagpur shrink pack limited, MIDC, Nagpur, Maharashtra. The products manufactured in this facility layout are poly vinyl chloride (PVC) blown

films, printed plastic labels, plastic pouches, food packaging plastic bags, etc. The total length (L) of the layout is 28.48 metres and the width (W) is 11.54 metres. The machines and their dimensions are given in Table 1. The material flow matrix is shown in Table 2.

TABLE 1: Dataset of case-study

Sr. No.	Departments	Length	Width	Area
1	Raw material storage	7.72	4.44	34.28
2	Mixing and compounding	7.72	3.40	26.25
3	Office	3.35	3.22	10.78
4	Extruder 1	7.96	3.22	25.63
5	Extruder 2	6.46	1.76	11.37
6	Slitting machine	2.71	3.20	8.67
7	Film cutting machine	2.50	2.74	6.85
8	Core cutting machine	1.60	3.70	5.92
9	Compressor room	1.40	3.70	5.18

TABLE 2: Material flow (Tons/month)

f_{ij}	1	2	3	4	5	6	7	8	9
1	0	27	-	-	-	-	-	-	-
2	-	0	-	22	5	-	-	-	-
3	-	-	0	-	-	-	-	-	-
4	-	-	-	0	-	15	-	-	-
5	-	-	-	-	0	2	-	-	-
6	-	-	-	-	-	0	10	3	-
7	-	-	-	-	-	-	0	-	-
8	-	-	-	-	-	-	-	0	-
9	-	-	-	-	-	-	-	-	0

In this problem, the layout shape is not rectangular. Some portion of the layout is unused. This unused space is shown in the current layout of case-study 4 as shown in fig. 6.7.

The grey shaded portion is used for material flow using hand trolleys. The original layout cost is 170.58.

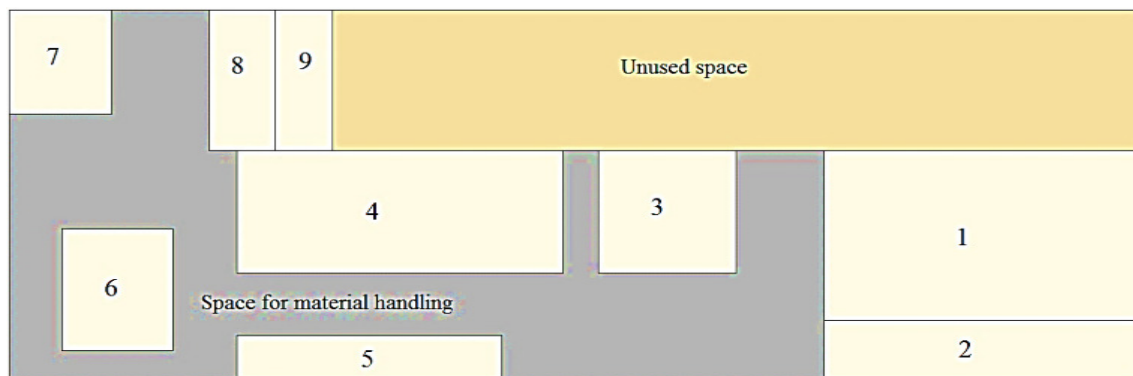


Fig. 1. Original layout of case-study (Nagpur shrink pack limited)

6.1 Results of case-study using FA and BBO

Case-study 4 is solved using the mathematical formulation

of unequal area FLP with fixed shape of facilities. The parameter setting of FA and BBO are shown in Tables 3. Both algorithm runs for 10 trials.

TABLE 3: Parameter setting of FA and BBO

Sr. No.	FA		BBO	
	Parameters	Value	Parameters	Value
1.	Number of fireflies (nff)	50	Number of islands	50
2.	Generations	100	Generations	100
3.	Absorption coefficient (γ)	2	Emigration (E)	1
4.	Randomization parameter (α)	0.3	Immigration (I)	1
5.	The attractiveness (β_0)	1	Mutation rate	0.2

TABLE 4: Results of case-study using FA and BBO

Sr. No.	FA		BBO	
	OFV	CPU time (s)	OFV	CPU time (s)
1	180.24	35	201.89	30
2	225.69	39	189.23	33
3	238.10	41	175.45	28
4	191.25	33	153.20	26
5	210.08	38	179.23	36
6	198.25	45	205.90	28
7	173.54	35	188.45	27
8	179.91	39	195.68	32
9	186.47	36	200.56	34
10	195.00	31	193.26	34
Average	197.85	37.2	188.25	30.8

Table 4 shows the results obtained using FA and BBO for case- study 4. The best solution is 153.20 and obtained using BBO. The computational time (CPU time) for FA and BBO to run each trial and its average is shown in Table 6.16. FA is also providing better results than the original solution but not better than BBO.

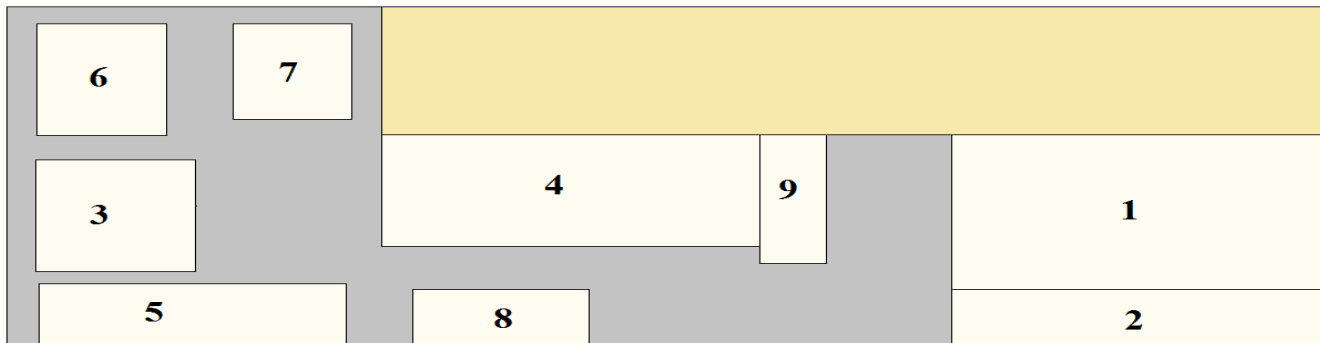


Fig. 2. Best layout obtained using BBO algorithm

The best layout obtained using BBO is shown in Fig. 2. It can be seen that the facility no. 3 is apart from the facilities carrying treatment of toxic material. Furthermore, the total layout cost is minimized as compared to original layout. From this case-study, it can be concluded that there will be requirement of optimized layout arrangement in the existing layout; which can optimize the total material handling cost resulting in long-time benefit to the industry. In this paper, FA and BBO algorithms are implemented to solve the case-study and it is giving better solutions than the existing solutions. The performance of BBO algorithm is better than FA. The CPU time to run BBO algorithm is less than FA. Therefore, BBO algorithm is efficient to solve FLPs.

7. CONCLUSION

An optimum layout is very important in practical point of view. The solutions of benchmark problems are little relevant to real life problems. Therefore, in this paper an industrial case-study is carried out to observe the real FLP. The FLP considered of plastic manufacturing industry consists of nine departments. FA and BBO metaheuristic techniques are used to obtain the best optimum results of the unequal area FLP of industrial case-study. The solutions obtained using both the algorithms are better than the total material handling cost of the original layout; however the performance of BBO algorithm is better than FA in terms of solution quality and the computational time. If the existing layout is modified according to the layout obtained in this paper, then the overall layout cost will be reduced which will be beneficial for the industry.

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A Literature Review on Facility Planning and Layout Design

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Abstract: Planning and pre work during a relocation of a plant in an Industry is very vast area to work on. Planning and pre work includes facilities planning, layout planning and systematic installation of equipment's and machines that are essential in a manufacturing industry. During working on facilities planning it is also important to work on the new proper streamline layout for the new plant. This proper streamline layout will not only increase the production but also minimize the material handling of the components. The purpose of this paper is to study and review the contribution of various researchers in the field of relocation and facilities planning.

Keywords: Layout, facilities planning, virtual layout planning, relocation.

1. INTRODUCTION

Proper installation of equipment's in the specified area in the plant is called facility layout problem. Facility layout problem plays an important role in the present and the future scenarios, it will have severe impact on major and long term material handling, lead time of product and work in progress as well as the efficiency will be affected. The proper installation of the machineries and the equipment's can definitely increase the productivity of the organization. Many researchers have worked on the type of facilities planning as well as facilities planning for the relocation of the facilities. It is very important to review the research papers to see if any research gap exists. It is also important to study research papers if any improvements can be done in this field.

The reason for relocation of an organization depends on various aspects like end of lease at current location, to make space for the new product, to bring the facility nearer to the customers, etc. While designing a new layout it is also essential to work on the optimization of the layout design. There are tools that can be used to optimize a layout design like heuristic method, simulation technique, etc. There are also lots of techniques that are used to assist for the problems that occur during designing a facility layout. These techniques are CRAFT, ALDEP, CORELAP, M-CRAFT, BLOCK PLAN, MULTIPLE, etc. Proper care must be taken that the efficiency of that organization should not be reduced while planning for new layout. Every organization needs that their productivity must be increased when they want to relocate or plan for new layout design.

2. TOOLS FOR OPTIMIZING LAYOUT DESIGN: HEURISTIC METHOD

These heuristic methods used for optimizing layout design are experimental or theoretical methods. There are many

heuristic methods that can be used to optimize the layout namely Simulated Annealing, Tabu Search, Genetic Algorithms. Tabu search is heuristic method first introduced in 1986 by Fred Glover. Tabu search is the extension of the local search technique which was used before the application of the tabu search technique. Fred Glover thought of tabu search as a Meta heuristic technique used for mathematical optimization.

Genetic algorithm is to solve the optimization problems; it was invented by John Holland in the 1970's. Genetic algorithm gives best optimizing solution from the results.

3. TOOLS FOR OPTIMIZING LAYOUT DESIGN: SIMULATION TECHNIQUE

Simulation technique is an artificial way to show the real processes or some real things. Simulation techniques shows the most realistic scenarios of the required area or space in the layout just like virtual reality or augmented reality. A simulation model is created as an analyzing technique to look for fluctuations in the future demands. Simulation techniques are used to assist management decision making where improper analytical methods are available.

4. REASONS FOR DESIGNING NEW LAYOUT

- Increase in the bottlenecks at the existing layout.
- For making the introduction of new machines in the organization.
- If the organization wants to change the design of the products or services.
- Relocating the plant
- The space available is less at the existing layout.
- Running out of lease.
- Improper material handling facility.

5. LITERATURE REVIEW

Ayşe Durukan Sonmez and Gino J. Lim (2012) discussed the two challenges occurring during the facility relocation related to the future demand change and uncertain number of the future facilities. A mathematical model was introduced to reduce the distance traveled by the customers in present as well as in the future. The performance of the mathematical model was compared to the various methods that were obtained in the literature surveys and also sensitivity analysis was performed. The objective was to minimize the sum of current weighted distance travelled by the customers to their closest facilities without exceeding the budget required for closing and opening of facilities.

Ali Taghavi and Alper Murat (2011) presented an iterative heuristic procedure for solving the problems related to the layout design and product flow assignment. Proposed a heuristic methodology to solve small to large problems with the best solution. An experimental study was conducted to compare the proposed solution method to the exact solution method. The results obtained were both effective and efficient solutions for any occurring problems. Further these tests can also be conducted on stochastic and dynamic extensions of integrated layout design.

M. H. Kulkarni, S. G. Bhatwadekar and H.M. Thakur (2015) presented a broad literature review on facility layouts and plant layouts. The brief study of literatures is done in area of facility layout problem, types and methodologies to solve the facility location problem. Authors also stated the need for the re-layout, layout configurations and inputs that will be required to design a proper layout. Also various aspects that are required while designing the layout such as area of the location, number of machines, numbers of products, etc. are discussed in this paper.

Sanjeev Naik and Dr. Shrikant Kallurkar (2016) published a review paper based on plant layout as well as re-layout. The tools that are required for optimizing the layout design are also mentioned in this paper. Talked about the heuristic techniques like Tabu search (TS), Simulated annealing (SA) and Genetic Algorithm (GA). Discussion was done on those research papers and the shortcomings were also found out in those papers. This paper is mainly focused on the optimization of the layout design and the tools required for optimization.

S. Jiang and A. Y. C Nee (2013) worked on the novel factory planning system for on-site facility layout planning (FLP). Two FLP modules are used by the author manual and automatic. An Augmented Reality (AR) layout was used for facility layout planning for the existing layout. An Augmented Reality (AR) based model of the layout is the computer generated image that shows the real world view of the layout. An Augmented Reality is used for visualization of the layout process like Proper installation of

the equipment's can be shown on the Augmented Reality (AR) system which can show if the equipment can be placed in that area. It was also stated that an Augmented Reality (AR) based facility layout planning (FLP) has some drawbacks like it can become ineffective for large scaled and complex layouts and manual planning can be challenging and difficult.

Eida Nadirah Roslin and Ong Gee Seang (2008) developed a design of a facility layout for the production line in the organization. WITNESS simulation software used for the facility layout design. A case study was conducted by the authors in a lubricant manufacturing company to work on its production line in the manufacturing department. WITNESS software uses various data such as process flow, machine cycle time, product cycle time, material handling, part delivery schedule, etc. to simulate and give the output. Using WITNESS simulation software two layout designs will be created based on the data provided. Analysis is done of those models of layout and the best model is selected between those two. By the simulation software two flow patterns are created namely S shape flow pattern and U shape flow pattern. After the studies were done U shaped design was found to be more effective compared to the S shaped design. Authors also stated that for future material handling, safety and proper arrangement of the machines and proper method of working to be done.

Hari Prasad N., Rajyalakshmi G. and Sreenivasulu Reddy A. (2014) created a layout design using a computerized relative allocation of facilities technique (CRAFT). The objective is to create an optimized layout by giving input of STEP file into the software. CRAFT was proposed by Buffa et al, and is also called as computerized heuristic algorithm. To develop a JAVA program inputs are required to be entered such as number of departments, initial layout of the organization taken from AutoCAD, cost matrix and flow matrix. The AutoCAD file of the initial layout should be converted into a STEP file format. It was seen that by using the CRAFT more than 50% of the cost was reduced of optimizing layout compared to the initial layout.

Srinivasan Rajagopalan and Sunderesh S Heragu (1997) did their research in the area of facility layout and material handling. To increase the productivity it is very important to provide a proper material handling systems and space while designing a facility layout. Many design related problems are faced due to less material handling space available which will discourage the workers and also the productivity becomes less, hence the authors discussed a methodology to solve these types of design related problems and any other problems. This paper also outlined an idea to solve the problems occurring in the material handling flowpath as well as pick up and drop off point location. They also talked about making a proper layout with a flowpath for movement of automated guided vehicles (AGV). AGV provides less material handling by

the humans which would result in less accidents and improper material handling. The authors also talked about quadratic assignment problem (QAP) which is one of the methods to solve problems occurring while layout designing.

S. Jiang, S. K. Ong and A. Y. C. Nee (2014) presented an augmented reality (AR) based hybrid approach for on-site planning of layout and evaluating it in real time. A system named an AR based hybrid approach to facility layout planning and evaluation (AHFLE) is used for automatic planning and manual planning. In AHFLE, parallel tracking and mapping (PTAM) is used for real time tracking of the activities done by the planner. Using AHFLE two plans are created manual and automatic. To find a best plan for the facility a multi attribute decision making (MADM) models are used. In MADM there two types to solve these decision making problems like information aided manual planning and analytic hierarchy planning (AHP).

Marvin A. Arostegui Jr., Sukran N. Kadipasaoglu and Basheer M. Khumawala (2006) compared the types of heuristic methods for facility layout problems (FLP). The mainly used heuristic methods are Tabu Search (TS), Genetic Algorithm (GA) and Simulated Annealing (SA). These methods were done on many types of FLP under different types of conditions like time limited, solution limited and unrestricted conditions. For the test the authors used three problem domains namely capacitated FLP (CFLP), multi period FLP (MPFLP) and multi commodity FLP (MCFLP). After the deep studies the author concluded that the results obtained by GA and SA are dependent on the problem type and the conditions used but TS shows overall good results for all types of conditions and problem types so this technique should be first applied. TS as compared to others yield better results so it should be tried first and also it is easy to implement.

N. Menck et al, (2012) discussed factory planning using the virtual reality (VR) technology. This VR technology provides human computer interface for the purpose of designing, analyzing, planning and optimizing any complex facility layout designs. VR can also help in fixing the problems such as whether the equipment's and machines can be placed at the given area or has no place for those machines. The virtual reality user interface (VRUI) software is used. Use of virtual reality will help in the future problems that can occur while shifting of the plant to the different location.

M. Iqbal and M. S. J Hashmi (2001) did design and analysis of virtual factory layout. Mostly factory layout is done on computer based software like AutoCAD but the drawback in this software is that they give the 2D layout of the factory which is difficult to visualize. To overcome this problem the authors implemented a virtual factory which will give the 3D view of the layout and help in visualizing the layout.

With use of VR setup the planner will be able to view the actual setup of the factory. With the help of VR problems that may occur in future like layout problems; flowpath and safety and material handling can be visualized and changed using techniques to solve problems.

V. Madhusudanan Pillai, Irappa Basappa Hunagund and Krishna k. Krishnan (2011) proposed a robust facility layout for the organizations. Dynamic plant layout problem (DPLP) assumes that the layout will change any time with low cost of relocation and low cost loss while interrupting production and machines that can be easily relocated. A robust design is a single layout that will have low cost of rearrangement and reduce loss of production while relocating. Simulated Annealing is proposed for the problem solving if any occur.

Jaydeep Balakrishnan, Chun-Hung Cheng and Kam-Fai Wong (2003) talked about the facility layout optimization using FACOPT which is user friendly and effective. Many researches are done on facility layout problems. There are some algorithms that can be used to solve facility layout problem but are not very easy to use and can mislead sometimes.

This FACOPT software uses two well-known methods namely simulated annealing and genetic algorithm. The FACOPT software uses data of the various departments to generate the layout then one of two methods is selected to generate the solutions to those layouts. Layout optimization can reduce the production cost. In addition to these methods of optimization Tabu Search method can also be done to find a solution to layout problem.

Vivek deshpande et al.(2016) presented a methodology of designing layout using computerized relative allocation of facilities technique (CRAFT) and automated layout design program (ALDEP). Many organizations want to increase the productivity by changing the layout of the facility. CRAFT is the technique in which some changes are done on the existing layout to increase the productivity while ALDEP technique is used to prepare an entire new layout of the facility. By using the CRAFT and ALDEP techniques there were some significant saving in material handling cost of up to 23%, which contributes in increasing the productivity.

6. DISCUSSION

Based on the literature review done on the facility layout planning and problems associated to the facility layout problems were discussed by many researchers. The main focus of the researchers for facility layout problems were on the heuristics methods for the optimization of the layout. There were many heuristics methods to work on but the best methods were Tabu Search (TS), Genetic Algorithm (GA) and simulated Annealing (SA) that were used. In these heuristic methods Tabu Search was found to be more

effective compared to the Genetic Algorithm and Simulated Annealing. All the results obtained by using TS, GA and SA were dependent upon test done on them and each showed different results but TS obtained most overall good results and should be tried first.

Many researchers also discussed on the planning of the layout done using software's like AutoCAD but it was difficult to visualize the layout so they used different techniques like Virtual Reality (VR), Augmented Reality (AR) to visualize the layout in the real life view. These techniques provide a better planning of layout as the problems that may occur in the future can be visualized and can be solved before final planning. WITNESS software is also used to make a proper layout which uses data of the organization to obtain a proper layout. New techniques like CRAFT and ALDEP also used by some researchers to make a layout in which CRAFT is used to redesign an existing layout while ALDEP is used to create new layout. These techniques the most widely used by the industrial designers which makes the work of designers easy.

7. CONCLUSION

Many organizations look to improve their productivity which can be obtained by optimizing the plant layout. The optimization techniques should be used to obtain these results but many researchers investigated on heuristic methods of optimization like TS, SA and GA. Alongside these techniques virtual reality and augmented reality are other two methods used while designing plant layout. Based on the literature survey many researchers used heuristic methods like tabu search, simulated annealing and genetic algorithm for optimization of layouts. For better results in the future both factory planning and optimizations can be done in one go using human computer interface and heuristic methods to proper and improved facility layout planning. Planning and Pre work of designing of layout and Facility planning is a wide area of study and should be done with taking proper care. Combination of the heuristic methods and designing software have never been done before which will give very good results if applied while planning for facility.

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Plant Layout Design of an Assembly Division of the Automobile Company

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Abstract: Facility planning is an arrangement of all physical configurations on the plant floor to optimize the best result by utilizing all the available resources in an efficient way. The paper is meant to optimize the new plant layout design of a transmission assembly plant, as it is company's requirement to expand its manufacturing capacity to cope up with the market's increasing demand. The detail literature survey has been carried out to find out the better technique to achieve the goal as mentioned. The data collection and its detail analysis have been conducted to develop the operation sequences. Some construction algorithms are selected and applied to develop layout alternatives and the best layout is selected based on the score optimized and the process sequence. To conclude the findings quantitatively, the frequency analysis is performed and the frequency matrix has been generated to justify that the layout selection based on qualitative analysis is the optimum layout.

Keywords: Systematic Layout Planning, SLP, CORELAP, Automated Layout Design Program, ALDEP, Automobile Industry, plant layout design

1. INTRODUCTION

The management of an automobile company has decided to expand its manufacturing capacity 10 times compare to its present capacity. This decision of the capacity expansion led to the conclusion to assemble the transmission unit in-house. The case study is about developing a new facility layout of transmission assembly line of an automobile company. The objective of the case study is to design a layout by using proper Industrial Engineering (IE) tools by which some of the 7 wastes can be eliminated at the design stage only. The paper explains the techniques and required data collection in the further sections of "Methodology" and "Data Collection". The analysis of the layout is conducted based on both; the qualitative analysis (using REL chart) as well as the quantitative analysis (using Frequency matrix) by using two algorithms: Computerized Layout Planning (CORELAP) & Automated Layout Design Program (ALDEP) and it is discussed further in "Analysis" section. Exact allocation of each facility on available space is described and concluded at the end of the paper.

2. LITERATURE SURVEY

2.1 Facility Planning

The reason behind investing time and resources for the systematic design of plant layout is the integration of the customers's requirement, materials (raw, finished, and in process), and machinery in such a way that all together create a single, well-functioning system. Classification of layout can be done based on the manufacturing system such as fixed layout, product layout, process layout, cellular layout (A Drira, 2007). The fixed product layout is

commonly found in ship or aircraft manufacturing industries which manufacture large size products. Process layout groups facilities with similar functions together. Product layout is used where production volume is high and a low variety of products, whereas in Cellular layout, machines are grouped into cells, to process groups of similar parts.

2.2 Various tools and techniques observed to design an efficient plant layout during literature survey

Systematic Layout Planning is a sequential guideline to the process engineer who is responsible to design a layout and the modified SLP diagram has been presented in figure1 (C S Tak, 2012). There are four stages: 1st is the data collection, 2nd stage is the analysis where the REL chart is developed and the total required space is then calculated. In 3rd stage, two construction algorithms are used to generate the alternatives: CORELAP & ALDEP which are the heuristic approaches to generate new layout. The final stage is the selection of the best layout among all alternatives based on the most suitable score.

Filippo De Carlo (2013) could successfully reduce throughput time by 3.9% and the worker moving time by 15% by using SLP technique. Lean concept along with SLP could reduce 4.15% in throughput time and 24% in workers moving time. The author could reduce the material handling distance by 9.017% by using CORELAP method by aligning the packaging process to operate it efficiently (I Hakim, 2015). Vivek Deshpande and Nitish Patil (2016) have applied ALDEP methodology and achieved the improvement in material handling cost by 23%, which are

in fact 44.75lacs rupees per annum with further benefits of increased productivity.

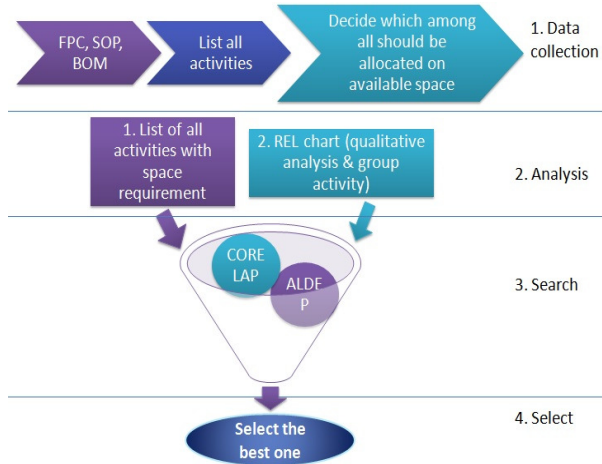


Fig. 1. Modified SLP diagram

3. METHODOLOGY

The process begins with required data collection which includes Flow process Diagram (FPC), Bill of materials (BOM), annual demand which decides the production rate, product variant, no. of manpower required, no. of workstations and type of material handling equipment required. Secondly, allocation of the facilities following the operation sequence by using some IE techniques like SLP, CORELAP and ALDEP which are applied to develop the alternatives and the optimal layout is selected based on the operation sequence followed and the score obtained. Furthermore, the selected optimal layout is then justified by comparing it with the result of the frequency analysis.

3.1 Data Collection

Figure 2 represents the Flow Process Diagram (FPC) of a transmission assembly line which is an essential data to decide what type of departments should be included in available floor space to design a layout.

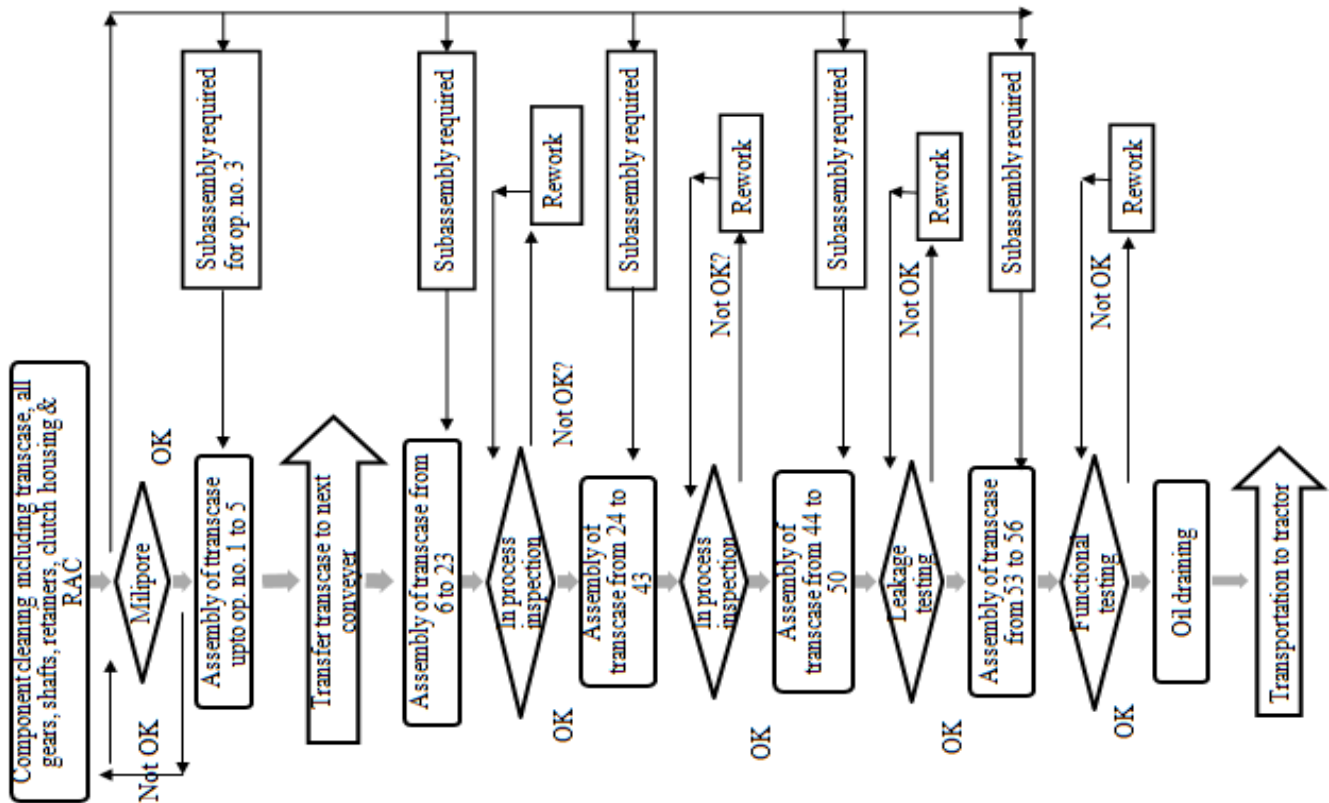


Fig. 2. Flow Process Chart (FPC)

After analyzing the FPC, the total no. of required facilities with its space has been optimized and shown in table form in figure 3.

	(dimensions are in meters)			
	Dept.	length	width	Total area
Store	1	35	20	700
Trolley area	2	5	5	25
Transmission (Trans.) Cleaning machine	3	7	2.8	19.6
General purpose cleaning machine (GPCM)	4	6	2.8	16.8
Rear Axle Carrier (RAC) and clutch housing (C/H) cleaning machine	5	4.05	3.1	12.555
Subassembly line	6	22	7	154
main assembly line	7	22	5	110
Millipore area	8	4	7	28
Total				1065.955

	m ²
Available space	1600
Required space	1065.95
Aisle width	426.38
Total required space	1492.33

Space comparison table

Space requirement of each facility

Fig. 3. List of facilities with required space

The aisle width should be at least 40% of total required space which has also been considered and mentioned in the second table of figure 3 (G K Agarwal, 2013).

3.2 REL Chart

REL chart is a group activity and to prepare the same, the opinion from all the heads and engineers has been involved in a project has been considered. It is developed by using 6 relationship indexes called: A-Absolute Important; E-Essential Important; I-Important; O-optional Important; U-Unimportant and X-Undesirable. The final REL chart and reasons for closeness is shown in table form in figure 4.

Department from/To	1	2	3	4	5	6	7	8	
1		A	E	I	I	I	E	U	Closeness rating
2	2		I	I	I	I	U	U	
3	2	2		U	U	U	A	O	
4	2	2			I	E	U	A	
5	2	2				E	U	A	
6	2	2		2	2		A	U	
7	2		1			3		U	
8			1	1	1				
Reason for closeness									

1	Min. distance for min. MH cost
2	Frequency
3	Operations sequence

Reason for closeness

Fig. 4. REL chart

3.3 Layout Generation

3.3.1 ALDEP Algorithm

Selection of the first department to place it on available space is performed randomly and the remaining departments are selected based on closeness rating with the previously placed department. There are total 8 departments and thus total 16 alternatives are generated by considering two directions for the placement and have been represented in figures from figure 5.

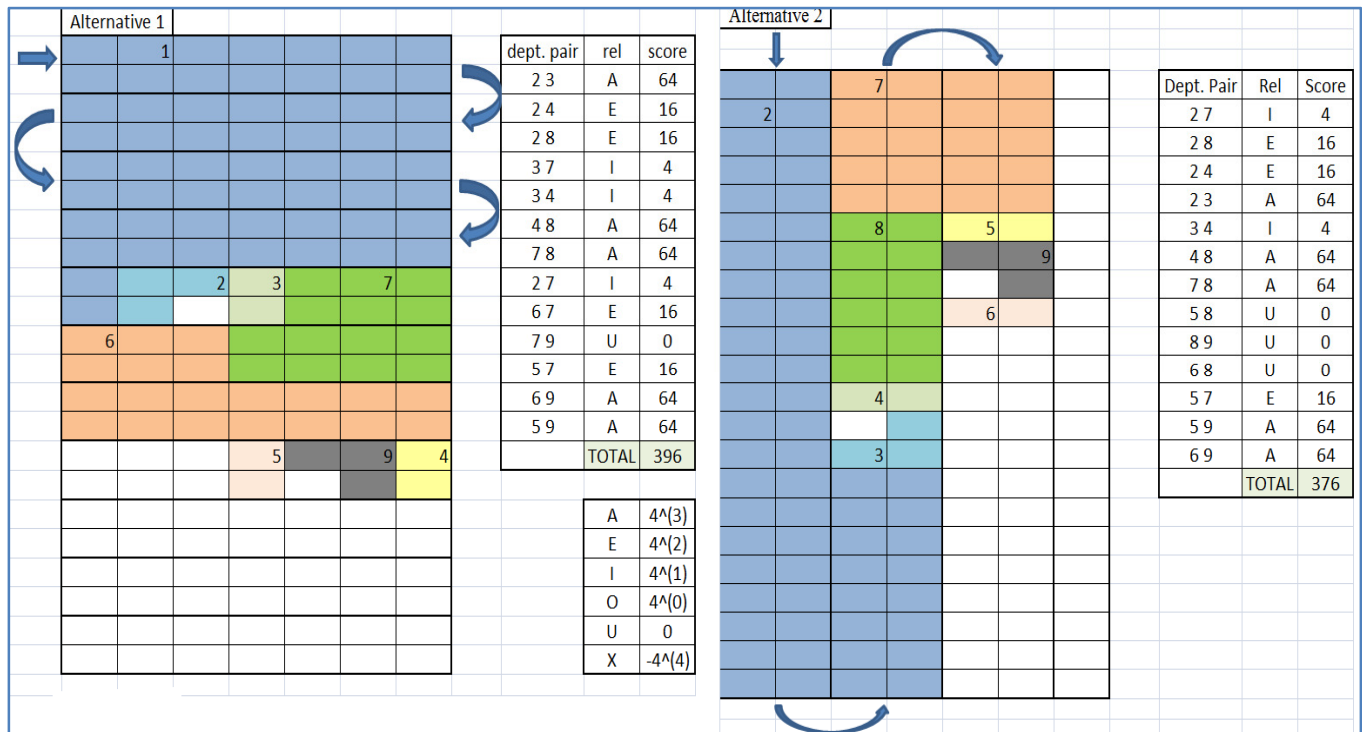


Fig. 5. Layout Alternatives by ALDEP method

The weight factors assigned to REL indexes are as follows: A: 4^3 ; E: 4^2 ; I: 4^1 ; O: 4^0 ; U: 0; X: -4^4 . The total score is calculated by summing weight factors of an individual pair and best layout is selected which has the highest score and also the one which follows the operation sequence. Figure 6 shows the total score table of all 16 alternatives with remarks.

No.	Score	Comment
1	396	Optimum, follows operation sequence
2	376	Not optimum
3	388	Follows operation sequence
4	384	Not optimum
5	364	Not optimum
6	380	Not optimum
7	384	Not optimum
8	380	Not optimum

No.	Score	Comment
9	372	Not optimum
10	380	Not optimum
11	304	Not optimum
12	368	Not optimum
13	320	Not optimum
14	380	Not optimum
15	316	Not optimum
16	344	Not optimum

Fig. 6. total Score of each alternative

3.3.2. CORELAP Algorithm

Assign weight factor to each closeness rating assigned to the pairs which are as follow: A-6; E-5; I-4; O-3; U-2; X-1. Figure 7 presents two tables: the first table of the facilities with their total score arranged in descending order and second table helps to decide the allocation of a selected facility with already placed facilities.

	Closeness ratings	Summation of rating	Total	Dept. to be placed	REL index with previously placed dept.	Total Weight Rating
1	A+E+I+I+I+E+U	6+5+4+4+4+5+2	30	7	1	81
6	I+I+U+E+E+A+U	4+4+2+5+5+6+2	28		E	
5	I+I+U+I+E+U+A	4+4+2+4+5+2+6	27	7	2	1
4	I+I+U+I+E+A+U	4+4+2+4+5+6+2	27		U	
2	A+I+I+I+I+U+U	6+4+4+4+4+2+2	26	7	1	82
7	E+U+A+U+U+A+U	5+2+6+2+2+6+2	25		E	
8	U+U+O+A+A+U+U	2+2+4+6+6+2+2	24			
3	E+I+U+U+U+A+O	5+4+2+2+2+6+3	24			
Descending order of the facilities based on total weight score				Options for the placement of facility 7 with the previously placed facilities		

Fig. 7. Weight assignment in CORELAP method

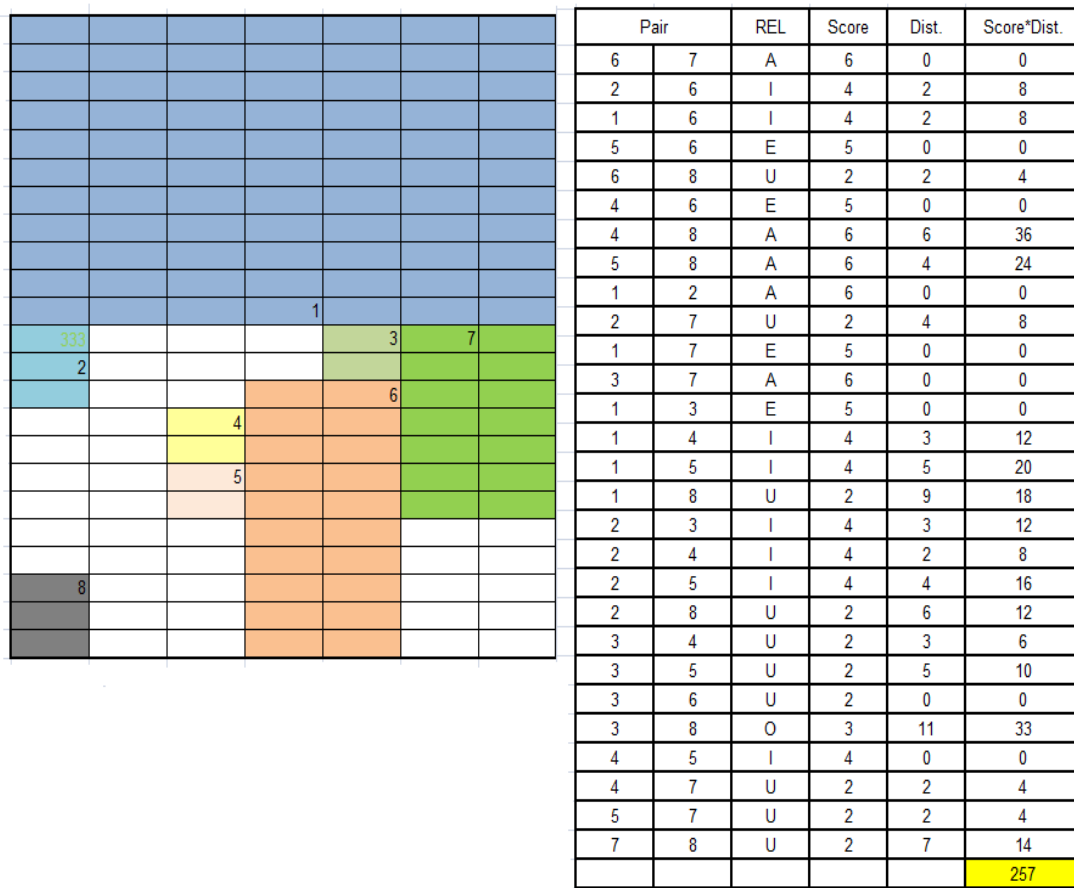


Fig. 8. Optimal layout using CORELAP method

Figure 8 shows the final optimal layout with its score selected by using CORELAP technique. As shown in the first table of figure 7, the dept. no. 1 should be selected and should be placed at the centre point of the layout. The sequence of the placement of the remaining department is based on its highest closeness rating score with the already placed facilities and it is explained in the second table of figure 7. The weight assignment to the closeness rating index of a pair is as follows: A-243; E-81; I-27; O-9; U-1; X-(-729).

3.4 The selection of the layout

The first alternative from the table mentioned in figure 6 and layout from figure 8 are the optimal layout derived by two algorithms. Comparison of both the layouts shows that there will be a requirement of U-shape assembly line if layout developed by using ALDEP is considered. Which will lead to the duplication of MH equipments and the movement of the flow will also become congested. This

leads to the conclusion to select the layout in figure 7 for further design.

Figure 9 represents the proper arrangement of all activities along with aisle width and table13 shows the name of activities allocated on floor space with number indications.

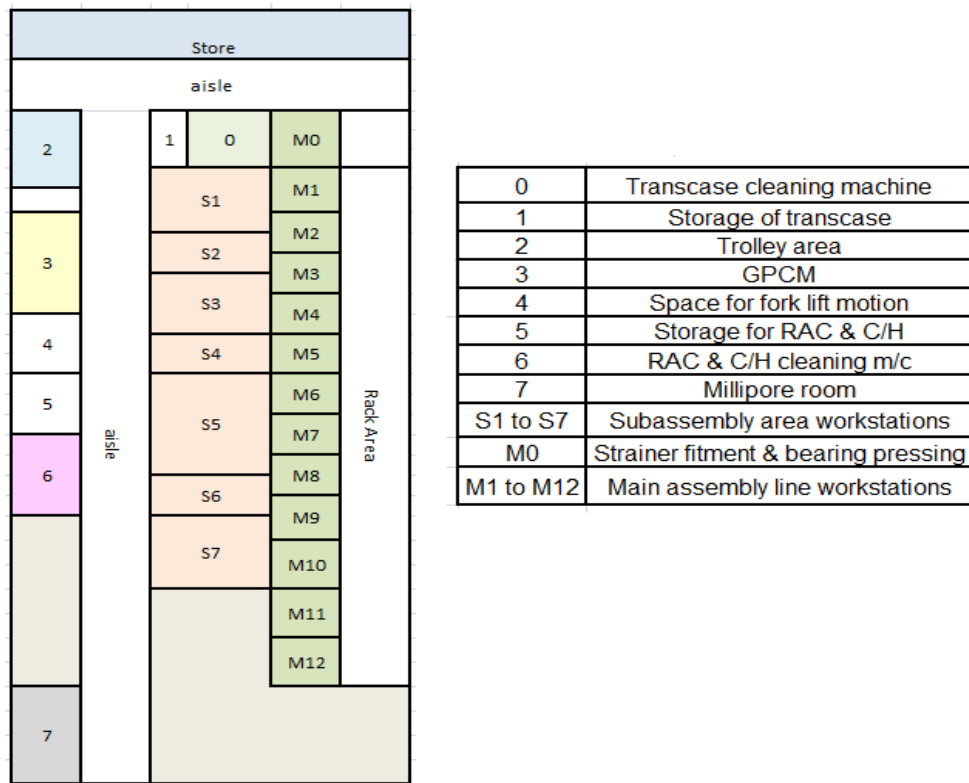


Fig. 9. Detail design of the optimal layout

4. FREQUENCY ANALYSIS

To understand the frequency between departments, one needs to understand what type of material and with what quantity need to be moved to follow operation sequence. To move the material from store to cleaning machine, kits are used and moved in hand trolley. These kits are designed

according to the dimensions of the material which needs to be moved from store area to general purpose cleaning machine and then from cleaning machine to subassembly area. One trolley carried one kit only. Considering this limitation, the total frequency between these two pairs of departments have been analyzed and identified.

TABLE 1: Frequency analysis

from/To	1	2	3	4	5	6	7	8
1				165		2	2	
2	165							
3							50	1/7
4						165		1/7
5						10		1/7
6		165					600	
7								
8								

Furthermore to supply empty transmission case and rear axle carrier from dock area to respective cleaning machine also been analyzed by counting no. of a unit on a palate and calculating the total no. of frequency between these two pairs of departments have been analyzed and mentioned in table1. Table 1 shows the frequency analysis per shift considering 50units per day.

It is quantitative analysis of the department pairs which justifies the placement of adjacent departments. As described in table 1 pairs such as trolley area & store, store & GPCM, transmission cleaning machine & main assembly line, GPCM & subassembly area and main assembly line & subassembly area are allocated next to each other in a layout.

5. RESULT DISCUSSION & CONCLUSION

The construction algorithms like ALDEP and CORELAP are applied here to develop the layout alternatives whereas Systematic Layout Planning method is used here to design a layout systematically. The Layout is optimized by applying IE techniques to eliminate some of the wastes such as unnecessary motions of resources, rework and delay. The best optimized layout is selected in this case as shown in figure 9.

The frequency matrix observation justifies the placements of the activity pair placement adjacent to each other as shown in table1.

It can be concluded that the layout design optimized is the best solution for the resources allocation on plant floor by observing and comparing the final layout design with frequency matrix as it is derived by applying IE techniques which considers all the wastes elimination at designing stage only. Thus the optimized design gives the best result which is justified.

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Optimization of Facility Layout for Improvement in Productivity

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Abstract: Plant layout or a facility layout is the design and installation of systems of men, materials and equipment. It is the joint determination of the locations, sizes and configurations of multiple activities within a facility. It illustrates a floor plan for arranging the desired machinery and equipment of a plant, established or contemplated, permitting the easiest flow of materials. It strives to achieve lowest cost with minimum material handling, in processing the product from the receipt of raw material to the dispatch of the finished product. The objective of this research is to study the existing plant layout of manufacturing unit and improve it using Systematic Layout Planning (SLP) theory for better plant area utilization and increased productivity. It indirectly reduces the throughput time. In this research, different types of Lean Manufacturing tools and techniques are used so that its ultimate effect will be on productivity and quality.

Keywords: Facility Layout, material handling, Systematic Layout Planning (SLP)

1. INTRODUCTION

ABC Industries is one of the prominent Aluminium Die Casting foundry in Pune region. ABC Industries has mastered the various manufacturing processes like High Pressure Die Casting, Gravity Die Casting, Die Casting Tool Manufacturing and Auto-components. It manufactures critical Engine and Transmission auto parts along with non-auto Die Casting parts for global OEMs. The combination of world-class facility and tie-up with Global Technology players has catapulted ABC Industries as "Best Die Casting Foundry "

2. LITERATURE REVIEW

The analysis of facility design such as layout and material handling system is very important in a manufacturing industry. Proper analysis of existing layout design could improve the performance of production line. It also helps in decreasing bottleneck rate, minimize material handling cost, thereby reducing idle time and enhancing the efficiency and utilization of resources. (C.N.Kulkarni, Dr. M.I.Talib, Dr. R.S. Jahagirdar, 2013). The productivity improvement is made through modification of shop floor layout which supports the multi machine manning and streamlining the material flow in between the machines. The cycle time analysis and part flow analysis is carried out to group the machines, which look more in detail on bottleneck processes. The analysis on machine utilization and layout of machinery is made to enhance the machining capacity of the shop floor. The selection of the best labour allocation strategies should simultaneously consider production output, lead times, and the amount of work in process inventories in the system. (Karthik T, Sentikumar M, 2012). The facility layout design defines how to organize, locate,

and distribute the equipment and support activities in a manufacturing facility to accomplish minimization of overall production time, maximization of operational efficiency, growth of revenue and maximization of factory output in conformance with production and strategic goals. (Md. Riyad Hossain, Md. KamruzzamanRasel, SubnataTalapatra, 2014). To increase the productivity, we have either to increase the speed or decrease the distance of the material path.

The distances are given by distances through which the material must move distances equipment must move, distances operators must move, types of handling equipment. (S. M. Kadane, S. G. Bhatwadekar, 2011). Facility planning is concerned with the design, layout, and accommodation of people, machines and activities of a system or enterprise within a physical spatial environment. (Garcia, A.D., Smith, McG., 2008). The facility layout design determines how to arrange, locate, and distribute the equipment and support services in a manufacturing facility to achieve minimization of overall production time, maximization of operational and arrangement flexibility, maximization of turnover of work-in process (WIP) and maximization of factory output in conformance with production schedules. (Huang, 2003). In manufacturing systems, the three main types of layout are product layout, process layout, and group layout, which is further categorized into flow line, cell, and centre (Askin R. G., Standridge, 1993). The product layout (flow shop) is associated with high volume production and low product variety, while process layout (job shop) is associated with low-volume production and high product variety. (Hesen, Renders, Rooda., 2001)

3. EMPIRICAL STUDY

In this section, an empirical study is presented to illustrate the application of facility layout for improving the productivity followed by String Diagram method.

3.1 Problem Statement

Causes that contributed to the need for a re-layout were identified as:

- Congestion and bad utilization of space.
- Excessive stock in process at the facility.
- Long distances in the work flow process.
- Simultaneous bottle necks and workstations with idle time.
- Labour anxiety and discomfort.
- Accidents at the facility.
- Difficulty in controlling operations and personnel.

In the secondary phase of this research, proper material handling techniques are defined to prevent the accidents and damages. This part will be focusing on design of new trolleys, zero pallet on the floor.

3.2 Methodology

Company focuses mainly to improve the productivity of plant. The research follows a systematic layout planning

(SLP) approach to improve existing layout of the ABC Industries. The detailed study of the plant layout such as operation process chart, flow of material and activity relationship chart was investigated. Final layout was selected by installation of new machine with effective utilization of area to improve productivity.

Process Flow for Systematic Facility Layout:

1. Streamline the flow of materials through the plant.
2. Facilitate the manufacturing process.
3. Maintain high turnover of in-process inventory.
4. Minimize materials handling and cost.
5. Effective utilization of men, equipment and space.
6. Make effective utilization of cubic space.
7. Provide for employee convenience, safety and comfort.
8. Minimize overall production time.
9. Maintain flexibility of arrangement and operation.
10. Facilitate the organizational structure.

There are more than 50 types of parts which are manufactured in each month at ABC Industries. All these parts belong to different part families. Every part goes through different processes as per the customer requirement. All parts are passed through High Pressure Die Casting Process.

Sample size of 15 parts is taken into consideration for this study. This sample size was decided based on Monthly Production Schedule-June 2017. The Pareto chart of this analysis is as shown below:

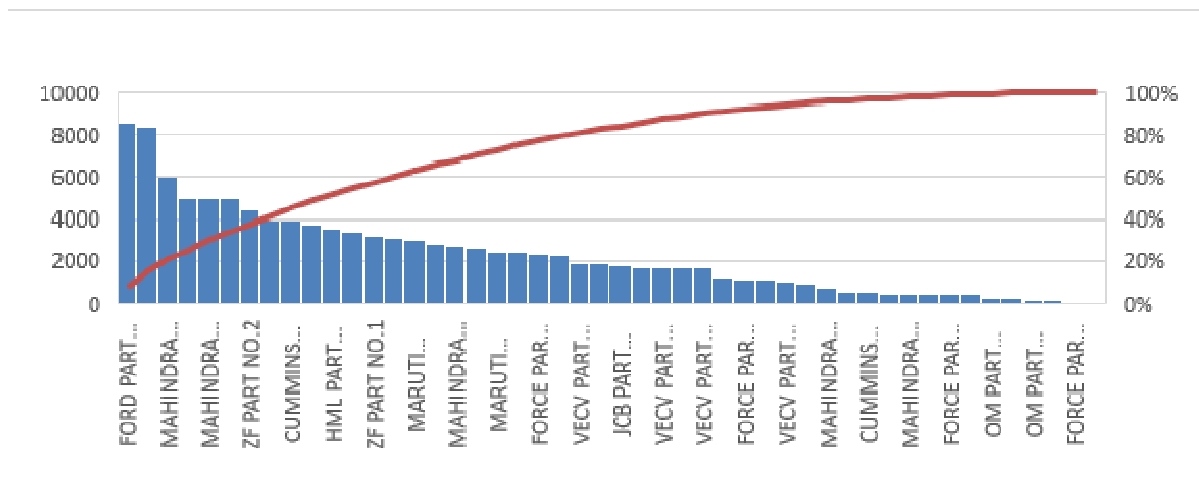


Fig. 1. Pareto chart for sample size selection

From the above Pareto Chart, few parts were selected based on their sales quantity. The result was concluded that the parts till VECV PART NO.2 carries the 80% of the total quantity. The flow of all these parts was studied with objective of minimizing the distance travelled and transportation time. Material flow analysis for one part (Cummins Part No.2) is illustrated in table no. 1. The part was selected based on its criticality of material flow through whole layout.

ILLUSTRATION: CUMMINS PART NO.2

- 1) Processes Involved:

TABLE 1: List of processes involved and feasibility of relevant engaged facilities

String Number	Process	Cycle Time per part (in Sec)	Feasibility of facility location movement
1	HPDC	120	NO
2	Riser Break	20	YES
3	Trimming	150	YES
4	Fettling	480	YES
5	Extra Burr Cutting	30	YES
6	Bend Removal	238.8	YES
7	Inspection	20	YES
8	Machining 1st setup	240	NO
9	Machining 2nd setup	252	NO
10	Washing	125	NO
11	Final Inspection	64.8	NO
12	Packing	6	NO
13	Dispatch	0	NO
		1746.6	

2) Existing Material Flow:

The standard sequence of processes followed by ABC Industries is illustrated in Figure No. 3.

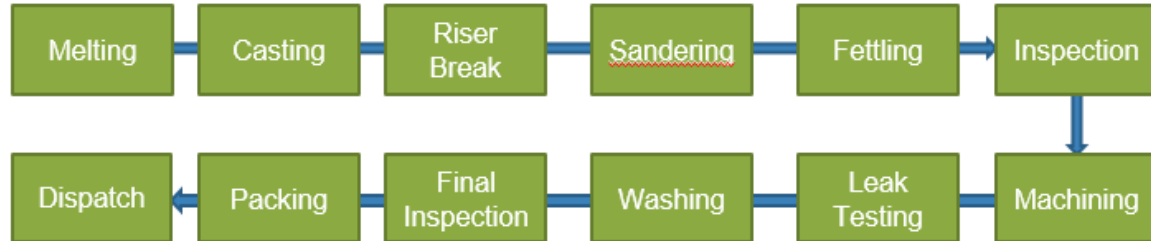


Fig. 2. Process Flow Diagram

- Melting: Alloy-AlSi9Cu3 is melted in the oil-fired furnace at the temperature of 660°C.
- High Pressure Die Casting: In die casting liquid metal is injected into a die of the exact shape in which, under pressure, it solidifies.
- Riser Break: A riser, also known as a feeder, is a reservoir built into a metal casting mould to prevent cavities due to shrinkage. This part of casting is removed using the cutting system.
- Fettling: It is the process of removing the unwanted metal e.g. flashings, riser, heat check mark etc. It includes the processes like punching, chipping, filing, grinding etc.
- Machining: It's a broad term used to describe removal of material from a workpiece, it covers several processes such as cutting, milling, drilling etc.
- Leak Testing: This process used to ensure quality control which helps to verify strengths of the product and guarantee customer safety.
- Washing: The viscous oil which is used in leak testing and the coolant used in machining is washed by this process.
- Inspection: The process of verifying the desired parameters meet the requirements.

To find out the distance travelled by each part, the part movement was plotted on string diagram and the total distance travelled was calculated by Euclidean Distance Method as shown in Figure No. 4

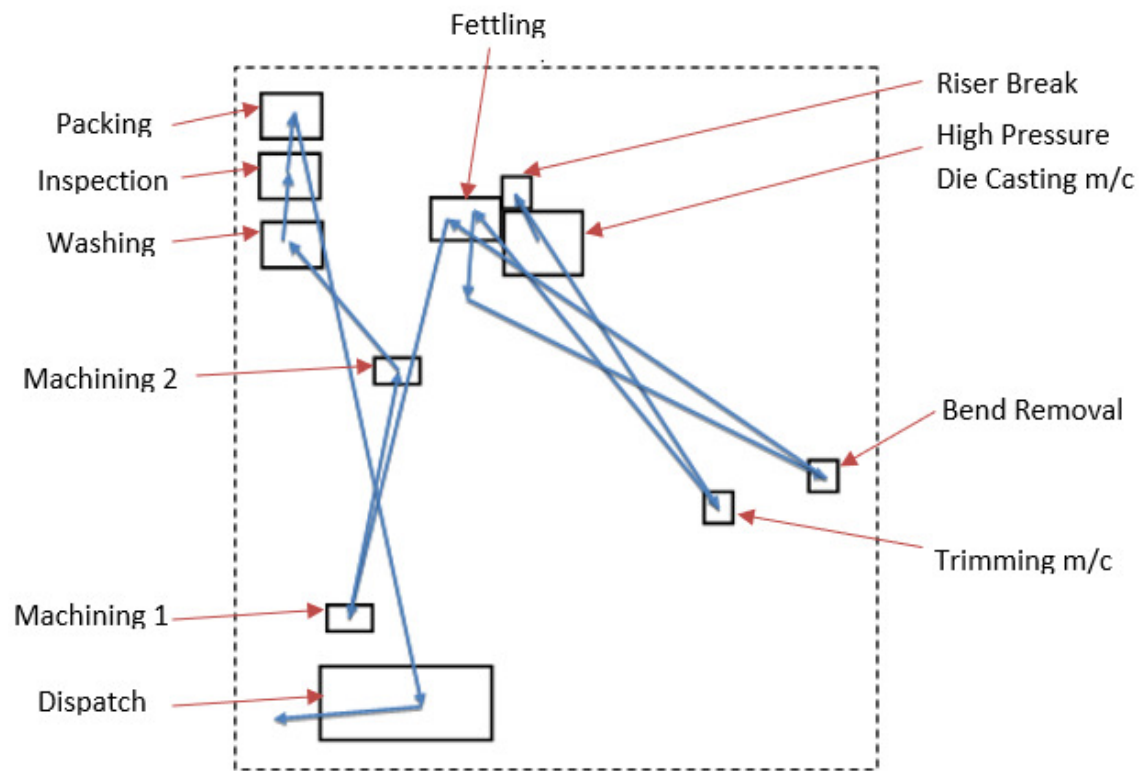


Fig. 3. String Diagram of Cummins Part No.2 (Existing Layout)

3) Distance Travelled:

The start and end processes were considered as High Pressure Die Casting (HPDC) Process and dispatch respectively. The distance travelled from melting process to HPDC was not considered due to some handling limitations.

TABLE 2: Distance Travelled and Transportation Time recorded (existing layout)

CUMMINS PART NO. 2		
From-To String	Distance travelled in meters	Transportation Time Per Part in sec
01 to 02	7	60
02 to 03	90	20
03 to 04	106	40
04 to 05	40.5	60
05 to 06	136	50
06 to 07	121	40
07 to 08	67.5	20
08 to 09	52.5	9.375
09 to 10	136	37.5
10 to 11	8	3.75
11 to 12	7.5	60
12 to 13	113	28.125
Total	885	428.75

Table No. 2 highlights the distance travelled and transportation time required for Cummins Part No. 2 in existing layout.

4) Proposed Layout:

In a proposed layout few facilities like Trimming Machine and Bend Removal Facility were shifted at Fettling process which was designed as per the feasibility report. The changes were undertaken considering the reduction in Work In Process (WIP) inventory.

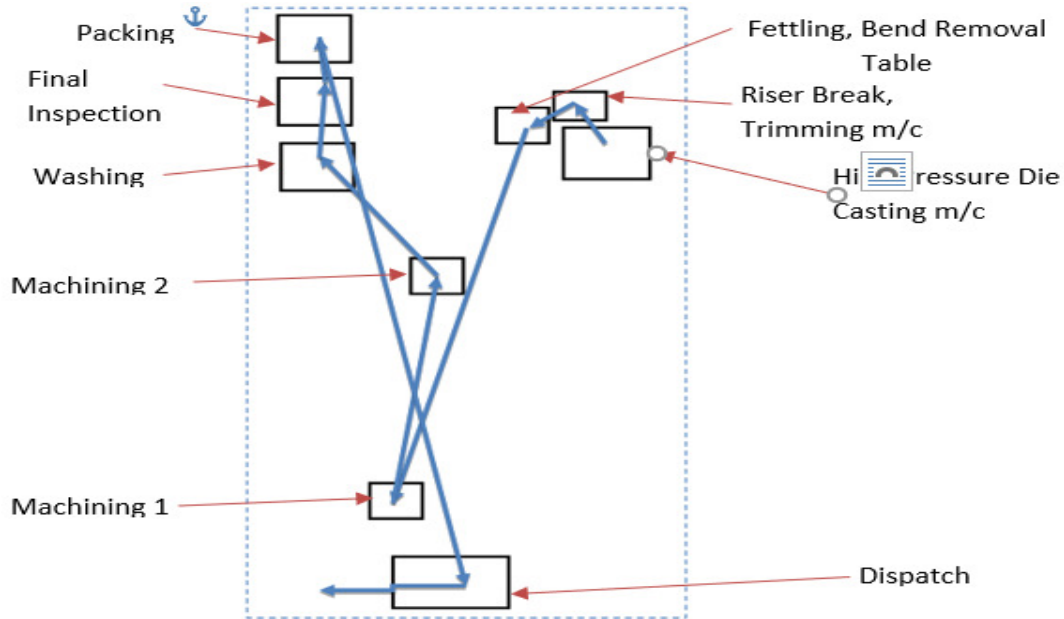


Fig. 4.

String diagram for proposed layout

4. RESULTS

Distance travelled after moving the facilities as per the proposed location:

TABLE 3: Recorded Distance travelled per part

Cummins Part No. 2		
From-To String	Distance travelled in meters (Existing Layout)	Distance travelled in meters (Proposed Layout)
01 to 02	7	7
02 to 03	90	1
03 to 04	106	1
04 to 05	40.5	40.5
05 to 06	136	2
06 to 07	121	2
07 to 08	67.5	67.5
08 to 09	52.5	52.5
09 to 10	136	136
10 to 11	8	8
11 to 12	7.5	7.5
12 to 13	113	113
Total	885	438

TABLE4: Percentage Reduction of Distance Travelled

Total Distance travelled				
Part Name	Quantity	Distance in meters(Existing Layout)	Distance in meters(Proposed Layout)	Percentage Reduction
Cummins Mount Gen	4000	3540000	1752000	49.5

Transportation time required for proposed layout is represented in table no.5:

TABLE 5: Transportation Time recorded

Transportation Time Required (in Sec)		
Cummins Part No. 2		
From-To String	Transportation Time per Part(Existing Layout)	Transportation Time per Part (Proposed Layout)
01 to 02	60	10
02 to 03	20	10
03 to 04	40	30
04 to 05	60	5
05 to 06	50	20
06 to 07	40	10
07 to 08	20	20
08 to 09	9.375	9.375
09 to 10	37.5	37.5
10 to 11	3.75	3.75
11 to 12	60	60
12 to 13	28.125	28.125
Total	428.75	243.75

TABLE 6: Percentage Reduction of Transportation Time

Transportation Time Required (in Sec)			
Part Name	Total trans. Time (Existing Layout)	Total trans. Time (Proposed Layout)	Percentage saving
Cummins Mount Gen	428.75	243.75	43.15

5. CONCLUSION

After the execution and analysis, it was found that the total distance travelled per part was reduced by 50%. New layout eliminated the backtracking of material flow, reduced material handling which ultimately resulted in less WIP as compared with the existing layout. Significant reduction in the manpower required for material handling was observed in the proposed layout. Implementation of the proposed layout prevented the amount of rework thereby reducing overall production time. New layout provides the high flexibility in arrangements and operations which directly

minimizes the investment on equipment. Due to effective utilization of the facilities, the idle time of machines was comparatively reduced than earlier scenario.

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Improve Productivity by Implementation of Facility Planning by Using Industrial Engineering Tool

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Abstract: Facility planning is anxious with the design/layout/arrangement of people/machines/activities of a system within a physical special environment. Facility planning is imperative in a manufacturing process/design field. There is 20% to 50% of the total costs of manufacturing is related to material handling and this cost can be minimize by applying effective facility planning in an organization. Various factors like decrease bottleneck operations, minimize the material handling cost, reduces idle/working time of machine, effective utilization of labor/equipment and space in the organization. The objective of this research is to improve the productivity by modifying in the plant layout /arrangement of a heavy loaded vehicle manufacturing company based on the systematic layout planning pattern theory (SLP) for improvement in productivity. Researcher used different tool like operation process chart, flow process of material/activity relationship for the present plant layout. Outcome of research shows significantly improvement in distance/ time used by operator and saving in floor space also.

Keywords: Material Flow, Production, systematic layout planning, Plant Layout.

1. INTRODUCTION

In today's world it is important to meet customers demand with excellent quality in product. It can be achieving by improving available resources like employees/machines and other amenities. Plant layout improvement is the tool by implementing it industrial productivities enhanced. In current development Plant layout design has become a necessary part of today's world. For creating the most effective plant layout researcher has focused on materials/machines/equipment, and other process.

2. LITERATURE

In this by Anucha Watanapa [1] suggested improvement in plant layout by, improving material flow operation, disassembly surface finishing and inspection sections. W. Wiyaratn and A. Watanapa [2] talked about manufacturing industry plant layout. In this research various sections of layout like material flow, operation flow process chart has been focused. By using systematic layout planning (SLP) method researcher proposed new plant layout. In this paper of R. Jayachitra and P. S. S. Prasad [3] Genetic algorithm (GA) tools used for design of cellular layout. WITNESS 2006 simulation software is also used. Uttapol Smutkupt, and Sakapoj Wimonkasame [4] has proposed layout design in improvement in total time, waiting time etc. with the help of Microsoft Visual Basic software.

3. PLANT LAYOUT PLANNING

In table no 1 engine assembly station facility is shown. In this handling capacity of per trolley/day and quantity for per day is shown.

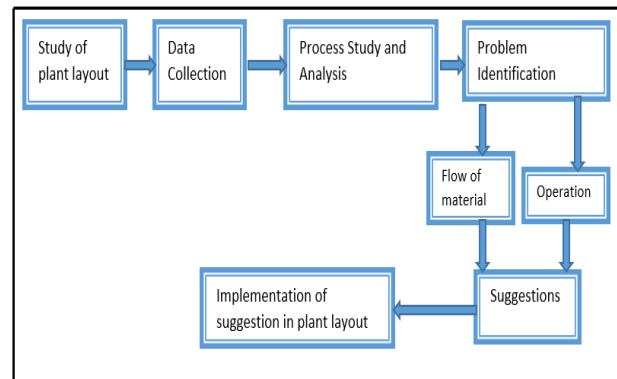


Fig. 1. Flow process chart of activity conducted in current research

4. ANALYSIS PLANT LAYOUT

In the current research plants various department/process is focused i.e. inspection section, machine/fabrication shop, surface finishing department and raw material storage section. Researchers found there is a improvement needed in flow/ storage of raw material department. Raw material storage is away from the plant area. By modification in this location material handling could be improved.

For the feeding of engine and transmission from the storage area to station separate trolleys are used so that operators have to move more distance for engine and transmission. There is no common tool kit for keeping the tool which is frequently used during operation so that more repetitive tool motions. There is 8 engine transmission inventory which

occupied more floor space. Location of rack and kit trolley is not proper and it is not in reach, so operators have to travel more distance to pick the material.

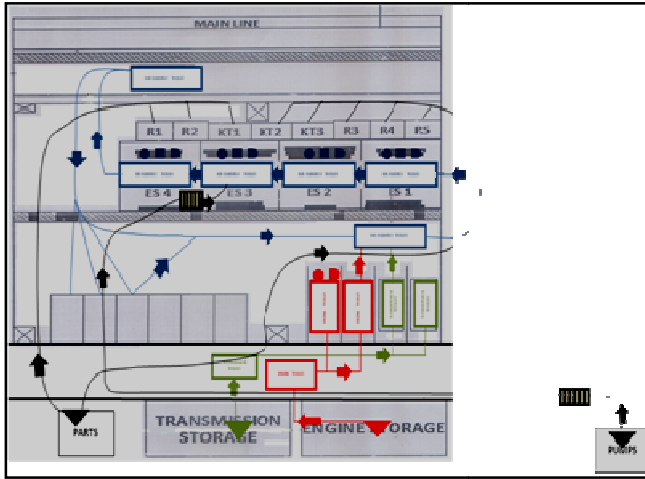


Fig. 2. Existing Layout

There are three stages for tightening process to set the torque of engine transmission 12 bolt, no provision of advance tool for deletion of 3 stage tightening of bolt (Loose, Impact Wrench, manual torque wrench).

In the current research vibrator compactor, loader/backhoe industry is considered. The original layout of Engine sub assembly station is shown in figure 2. Handling capacity per trolley and required quantity per shown in Table 1.

TABLE 1: Engine assembly station facility			
Item namex	Handling capacity per trolley	Required quantity per day	
Engine + Transmis sion Trolley	1 item	8 item	
Engine Feeding Trolley	1 item	4 item	
Transmis sion Feeding Trolley	1 item	4 item	
Material Rack	9 item	5 item	
Kit Trolley	9 item	3 item	

5. METHODOLOGY

In current research, proposed layout is design on the basis of flow process chart (man type) (fig. 3) of engine sub assembly.

TABLE 2: Flow process chart (man type) for existing layout

ENGINE ASSEMBLY

OPERATION	○	→	□	▽	Distance in Meter	Time Second
pick engine lifting sling						
move 8 steps with crane to engine line storage					5.6	7.33
move 15 steps to get engine subassembly trolley					10.5	13.75
back to engine line storage					10.5	13.75
hooking crane to engine						
pull engine s/a trolley to E1 stn(8 steps)					5.6	7.33
move 3 steps to rack4					2.1	2.75
pick bolts(4 nos.) 613-08025(8*25)						
move to rack5					2.1	2.75
move to tool post 1(3 steps)					2.1	2.75
position it on bolts to tight them						

move 3 steps to tool post 1				2.1	2.75
move back to stn(3 steps)				2.1	2.75
position torque wrench on fan mtg bolt 1 by 1 with 20 deg rotation					
place all tools to tp1				2.1	2.75
Total				44.8 m	58.66 sec

For optimum space utilization and reduce travelling distance load score method is used for layout analysis. In this method in step1 matrix made based on department/machines for load/frequency. In step 2 distance matrix is made for current layout. Finally total matrix is made. This matrix help in calculating load distance score for engine assembly. This lead to fabrication of flow process chart (Man type) process chart shown in (fig. 3).

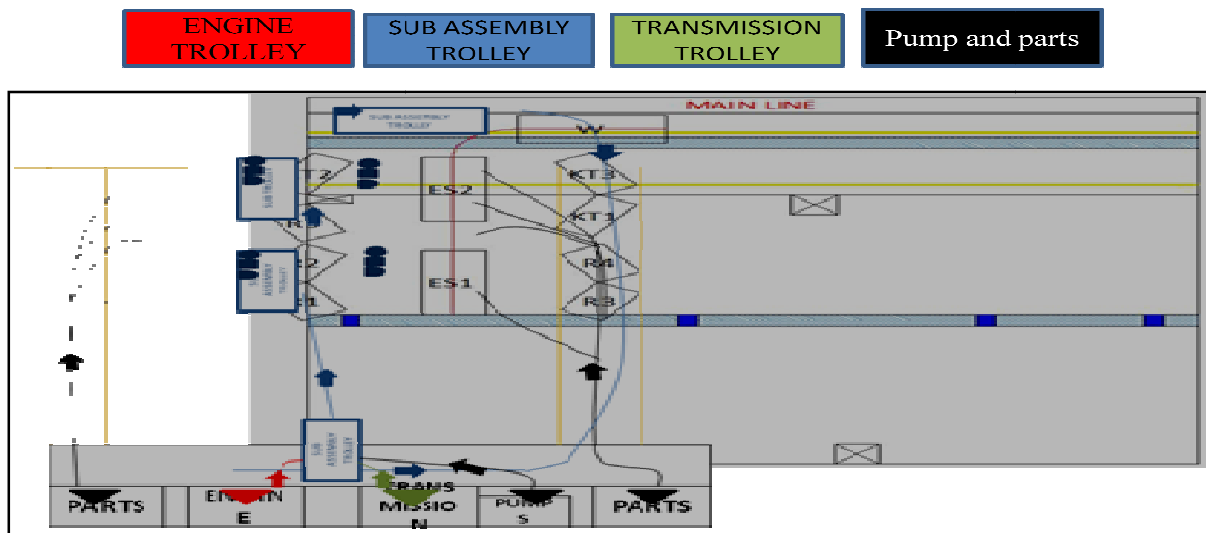


Fig. 3. Propose layout

Engine is shifted between parts and transmission Parts location is spited in two stations for smooth flow of process by applying this total distance travelled minimized

6. CONCLUSION

After applying Industrial Engineering tool, the productivity of engine sub assembly line boosted. There are some outcome of research Floor space has saved by 38.36%, total distance travelled reduce by 58.75%, By flow process chart 50% station inventory has been reduced and 58.33% material handling time is also saved.

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A Dynamic Facility Location and Relocation Problem on Time Dependent Weights in Manufacturing Process Layout

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Abstract: This Research paper a Multi facility location problem with single Relocation opportunities is investigated. The weight Associated with each demand point is a known function of time. We take Euclidean distances and Rectilinear, squared Euclidean. Relocations can take place at predetermined times the objective are function is to be minimize the total location and relocation costs. By use of algorithm which can find the optimal location, relocation times and the total cost, for all three types of distance measurements and various weight functions, is developed by Locations are found using constant weights and relocation time are the solution to a Dynamic Programming or Binary Integer Programming (BIP) model. The time horizon can be finite or infinite.

Keywords: Discrete- horizon, Relocation, Time dependent, Location, weight function

1. INTRODUCTION

Dynamic facility location models can be considered to be extensions of the conventional (single-period or static) models as they include time varying demand. Most of the models developed in the literature for dynamic location problems assume that facilities can be relocated between periods in response to changes in demand. There are associated relocation costs for changing the location of facilities between periods, which can represent the initial investment for establishing new facilities and the cost savings for the closure of Existing facility.

Most of the continuous and discrete static location problems are known to be NP hard. Dynamic location problems are at least as difficult to solve as the static problems due to the additional consideration of time. However, the algorithms and solution approaches developed for static location problems can be adapted to solve the dynamic problems. Throughout this section we review the literature in dynamic facility location. We separate the dynamic models into continuous and discrete location models

Facility location has an important role because the site selection directly relates with the warehouse systems, inventory control and handling, customers and suppliers. A good location gives a strategic advantage against competitors. To give service to potential customers better by short distances stated by Jayaraman and Vaidyanathan, 1998. As locating more outlets a company enhances its accessibility and hence improves its overall customer service. John Mills, 2004 said that the determination of a

facility location is a well-known phenomenon in operational research area. The facility location means the placement of a planned facility with regard to other facilities according to some constraints. There are both quantitative and qualitative methods applied for the facility location problem. Chen, 2001

2. LITERATURE SURVEY

Facility location is a strategic management decision. Such a decision is usually made applying the current conditions such as population, infrastructure, service requirements and others Kim et al., 2000 Common location models deal with single and multiple facility location, covering p-median, p-center problems, their Applications and extensions. Many of these problems can be very difficult to solve. It is not surprising that so much work has focused on stochastic and deterministic problem formulations. While such formulations are reasonable research topics, they do not capture many of the characteristics of real-world location problems.

The strategic nature of facility location problems requires that models consider some Aspect of future uncertainty. Since the investment required by location of planning of lay out. The problem of facility location truly involves an extended planning horizon. Decision makers must not only select locations which will effectively serve changing demand over time, but must also consider the timing of facility expansions and relocations over the long term . Ficko, 2004 a series of static deterministic optimal solutions to solve the dynamic problem of locating a single facility

warehouse so as to maximize profits over a finite planning horizon. For each period in the specified horizon, he solved for the optimal warehouse location, establishing a set of potential “good” location sites. Dynamic programming is then used to determine the best schedule for opening a subset of these sites as an “optimal” location and relocation strategy for the planning period. [Tompkins, 1996].

This method finds the RI best solutions in each period t through an iterative procedure of solving integer programs with Benders’ decomposition. The number of solutions (R_i) varies by period and is found through bounding the overall optimal solution value. The expanded set of potential location sites for each period is then used in a dynamic program to determine an optimal location and relocation strategy. Note that both of these papers allow for frequent facility relocation Heragu, 1990. This approach was later found to be sub-optimal, but neither considers construction time or cost of relocation in the objective function. Extended the single facility location problem to a model where the facility location could change in a given time interval. In his paper, Wesolowsky presented an Algorithm for calculating the optimal location when the cost. [Ficko et al, 2004].

(Jain et. al, 2013) the results for a single facility dynamic location relocation problem these results are helpful in finding optimal initial decisions for the infinite horizon problem by using information only for a finite horizon. The proposed a forward algorithm for the solution of a single facility dynamic location/relocation problem. In their paper, the problem is reformulated in terms of a shortest path problem in an acyclic network and provides a condition for the existence of a finite forecast horizon for obtaining an optimal initial decision. (Garcia, 2013; Radicchio, 1970)

Amine Drira, 1975 defines in his review, different types of facility layout problems and has discussed various problem formulation methods the different facility problem solving techniques with more Emphasis on dynamic facility layout problems. He has derived a rough tree structure to present an idea of different considerations while developing a plant layout. The Reviewed about techniques that are used to optimize single objective functions and evaluated various variety of space allocation problems and uses of different algorithm to solve these space allocation problems with detailed review of facility problems/space allocation problem. The authors also discussed limitations of different algorithms and research gaps in automation of facility layout solving tools which are commercially available, SaChine, 2010.

The review in multi criterion facility location problems and has categorized multi criterion facility problems in to three categories, which are bi-objective, multiobjective and multi-attribute. The authors also discussed about methodology to be used to solve these categories problems

and briefly mentioned about criteria’s that are used in literature to solve facility location problems. (R.E. Love et al., 1975) A study on the cellular layout, cellular manufacturing system has been done and a case study has also been done to illustrate the benefits of cellular layouts .[Heragu, 1980]. The travel diagram technique could be used to minimize wastes of maintenance time, manpower and money and to generate higher profits for the same work from the same resources. [Jain, 2013]. Systematic Layout Planning (SLP) procedure has been used to modify the plant location

The Plant layout in cellular manufacturing firm to improve the productivity of the firm. [Garcia, 2013]. An Extension of the CRAFT algorithm that aimed to solve complex layout problems has been developed and the results were compared with that obtained from literature. [Tompkins et al., 1996]. Location models can also be classified as deterministic or stochastic. Deterministic models assume demand and other data to be known with certainty. Stochastic models incorporate information on the uncertainty of data and aim to determine solutions that perform well under all possible data realizations, according to an objective derived from the objective of the deterministic version of the model, such as maximizing the expected performance or minimizing the worst-case performance

3. METHODOLOGY

The minimum problem consists of locating a Dynamic facility in the plane with the aim of minimizing the sum of the weighted distances (the maximum weighted distance) to m given points. We present two solution methods for generalized versions of these problems in which.

- i) Location is restricted to the union of a finite number of convex polygons; (ii) distances are approximated by norms that may differ with the given points; and (iii) transportation costs are increasing and continuous functions of distance. Computational experience is described
- ii) The objective of the facility. Whether planning a new facility or the improvement of an Existing facility, it is essential that the product to be produced or service to be provided be specified quantitatively. Volumes or levels of activity are to be identified whenever possible. The company under study is concentrating on the rubberized coir mattress production with annual Installed capacity problems that hinder the smooth material flow and it has also been observed that there is a lack of scientific layout planning.

The Euclidean distance between point’s p and q is the length of the line segment. In Cartesian coordinates, if $p = (p_1, p_2, p_n)$ and $q = (q_1, q_2, a_n)$ are two points in Euclidean distance n space, then the distance from p to q is given by

The Euclidean norm measures the distance of a point to the origin of Euclidean space:

The last equation involves the dot product. This is the length of p, when regarded as a Euclidean vector from the origin.

$$f(x, y) = \sum_{i=1}^m w_i [(x - a_i)^2 + (y - b_i)^2]^{1/2}$$

We use the following notation:

X= (x, y)

location of the new facility

P= (a_i, b_i) location of existing machines, i=1, 2, 3m

W_i "weight" associated with maintenance hours and distance

Between Existing facility & machine i=1, 2, 3

The plant was visited for collecting the data. The manufacturing of this component is done by Functional or process manufacturing processlocation, stretching a giant

rubber band around all the pegs, and releasing the rubber band.

The region that the rubber band encloses is known as the convex hull of the existing facility locations. Any optimal solution to the location problem will be inside the convex hull, as the knot representing the optimal new dynamic facility location would never go into Equilibrium outside the convex hull. Facility planning determines how an activity's tangible fixed assets best support achieving the activity's objective. This includes activities such as facilities location, facilities design, facilities layout, or plant layout.

A Dynamic or adaptive strategy will have several time windows each one period long, and a flexible strategy will choose the time windows to minimize the total cost and includes robust and dynamic strategies as special cases where they are appropriate. The robust machine layout sub problem is represented with an integer programming formulation. Its objective function includes both material handling and machine rearrangement cost.

Data from manufacturing industry

	Existing facility Center			Proposed facility Center		
Sr no	Actual distance from facility Centre	Total maintenance in hour(1 year)	Distance in sq.turns=(2x actual distance x total maintenance(in hours)	Actual distance from facility Centre	Total maintenance in hours(1 year)	Distance in sq. Turns= 2xactual distance total maintenance (in hours)
1	17.5	72	2520	11	72	1584
2	19.5	46	1794	12	46	1104
3	19.5	22	858	15	22	660
4	20.3	36	1462	19	36	1368
5	26	16	882	08	16	256
6	30	24	1440	11	24	748
7	30	22	1320	06	22	704
8	26	24	1248	21	24	1108
9	25	24	1208	24	24	1152
10	26	40	2080	23	40	1840

4. DYNAMIC FACILITY LOCATION PROBLEM

Facility planning determines how an activity's tangible Fixed asset best support achieving the activity's objective. The optimum allocation of space to the components of the system is the main aim in developing a layout for a system

producing goods or services. Basically, facility planning means to determine the best arrangement of facilities and equipment in such way that it is capable of satisfying anticipated demand (quantity, quality, and timing) at lowest cost. The facilities that are planned today must help an organization to achieve Supply Chain Excellence. Supply

Chain Excellence is a process with six steps or levels. These steps are Business as Usual, Link Excellence, visibility, collaboration, Synthesis and Velocity. Business as standard works as when a company works hard to maximize its individual functions. The goal of individual department, such as finance, marketing, sales, purchasing, information technology, research and development, Manufacturing, distribution and human Resources is to be the best department in the company. Organizational effectiveness is not the Emphasis. Each organizational element attempts to function level

5. RESULT & DISCUSSION

- Analysis of optimum facility location of Maintenance shop by using Euclidean model. Comparison between existing and new location is carried out.
- The facility of common facilities has also contributed in Enhancement of availability of plant equipments.
- I have finally proposed the location that gives us the optimum maintenance travel time for maintenance work.

With the help of Facility Location Planning Tool (Euclidean with minisum location method) we find out the optimum location for new Facility center of co-ordinates From new location Net savings in distance traveled (in meters)

Saving Maintenance Traveling Time (Distance) in percentage % =	1.03%
Net Saving Travelling Distance in percentage % =	24.6

6. CONCLUSION

- Meet the economic demand: minimize investment in equipment and material handling cost.
- Meet the requirement of product design and volume.

Meet the requirement of process equipment and capacity: minimize overall production time; maintain flexibility of arrangement and operation; minimize variation in types of material handling equipment; facilitate the manufacturing process. The algorithm generates the optimal relocation times, and the optimal location of the facility between two consecutive relocations, such that the total location cost is minimized.

- Reduced inventory in process.
- Safe and proper material handling.
- Optimized use of service facilities
- Reduce the maintenance time

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Systematic Layout Planning (SLP) of S101 Engine Plant

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Abstract: This paper presents an analysis on a production shop floor layout of S101 Engine manufacturing set up and the application of a systematic layout planning (SLP) procedure, as an approach to solve the production shop floor layout problem.

Major manufacturing facilities required for S101 engine are Engine Head and block machining, Engine Assembly and Engine Testing. Total area requirement for S101 Engine plant was 21, 000 Sq. Meter as against 17, 000 Sq. Meter available area in MHEPL plant. The total area was optimized using systematic layout planning technique. P-Q analysis, relationship diagram, alternative evaluation tools were used from SLP for problem solving. The relationship between machines, operation activities, service departments and material flow are used to determine the optimal location of each machine and service departments. SLP technique has been employed to design the multiple alternatives of production shop floor layouts and compare the performance between new layouts in terms of material flow distance, traveling time, etc. Lean approach used to design total material flow, in process inventory and brought out part material storage. An improvement scheme is proposed after analyzing PFEP (Plan for every part) and material flow. This paper focus on effective use of PFEP in systematic layout planning. Remaining floor space deficit was fulfilled by effective use of MHEPL existing plant area and optimum use of exiting service departments. The alternative layouts were developed based on minimum distance traveled between each machine. It improved the layout by reduced total movement traveled in production for material handling. The measurements covered the actual sizes of the layout and machines, activities between machining cell, assembly and testing, distance between them, and material flow between all manufacturing departments in the company. The proposed procedure is illustrated to be a viable approach for solving production shop floor layout design problem through a real-world case study. As a result of successful implementation of SLP, effective utilization of MHEPL assets and manpower achieved. Scope for further expansion is also kept for future variants of engines. 3, 237 Sq. Meter storage area proposed against earlier requirement of 4979 Sq. Meter (34% optimization).

1. INTRODUCTION

With rapid increasing of demand in production, industrial factories need to increase their potentials in production and effectiveness to compete against their competitors. At the same time, the production process needs to be equipped with the ability to have lower cost with higher effectiveness. Therefore, the way to solve the problem about the production is very important. There are many ways i.e. quality control (QC), total quality management (TQM), standard time, plant layout to solve the problems concerning productivity.

According to the many researchers plant layout is one way to reduce the cost of manufacturing and increase the productivity. Also increases good workflow in production route. This research describes original plant layout, material flow analysis, which includes area and distance between operation A and B. MHEPL plant was selected for laying down new facilities required for S101 engine manifesting. The basic industrial layout planning is applied to systematic layout planning (SLP) method in which showed step-by-step of plant design from input data and activities to evaluation of plant layout. This method provides the new

plant layout that improves the process flow through the plant, and help to optimize space in plant.

2. PROCEDURE FOR PLANT LAYOUT PLANNING

Detailed process flow diagram prepared from store to dispatch of the engines. End to end process was mapped along with support/service department requirement. The data were collected and the number of tools/ equipment for manufacturing was counted in terms of the direction for raw materials and product. The operation process chart, flow of material and activity relationship chart have been used in analysis. The problem of the plant was determined and analyzed through SLP method to plan the relationship between the equipments and area. The framework of SLP is shown in Fig. 1. Based on the data such as product, quantity, route, support, time and relationships between material flow from –to chart and activity relation chart are displayed. From the material flow and relationship activity in production, the relation between each department can be observed. Then the results were drawn through the comparison between the layout options.

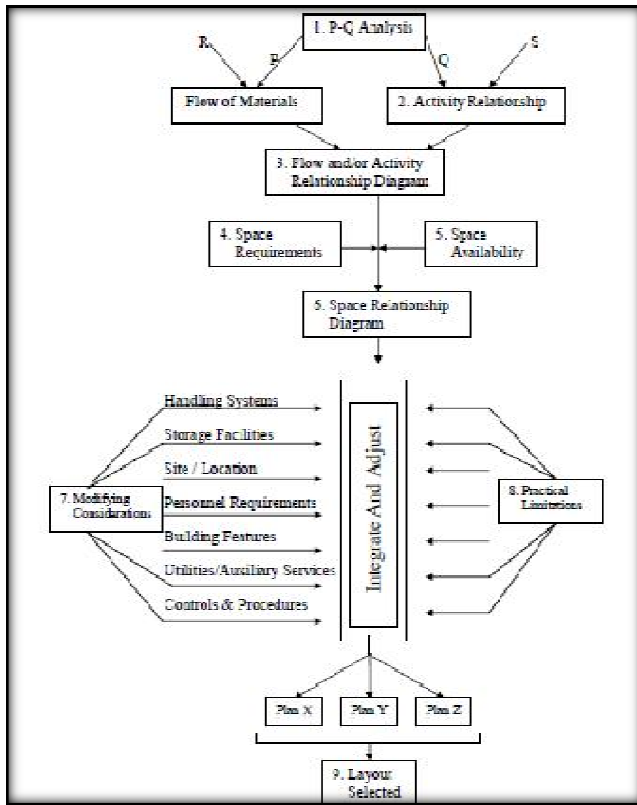


Fig. 1. Block diagram of Systematic Layout Planning technique

Volume data	
S101 Gasoline 3 Cylinder Engine	63000
S101 Diesel 3 Cylinder Engine	72000
S102 Diesel 4 Cylinder Engine	10000
S102 Gasoline 3 Cylinder Turbo charge Engine	40000
Total Volume	185000

Fig. 2.

PQ Analysis

Engine Models and yearly volume studied for TAKT time calculations and basic flow design.

Flow of Material

Basic Flow of material is explained as below:

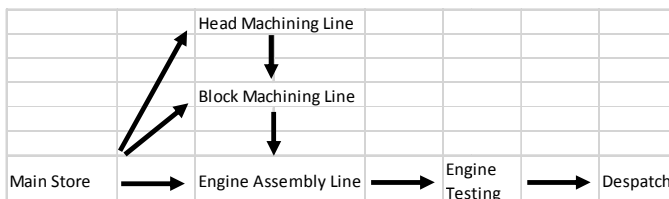


Fig. 3. Block diagram of Systematic Layout Planning technique

SPACE REQUIREMENT

SPACE REQUIREMENT FOR MACHINING LINE

Space or Area requirement of Machining line is calculated as per following formula

$$\text{Total Area Requirement} = \text{Length of Machining Line} \times \text{Width of Machining Line}$$

Total Length of Machining Line=

$$\left[\sum_{y=1}^{y=n} Ay + 1.5 \times Xn \right]$$

Width of Machining Line=

$$[Max(Bzn) + 1.5]$$

Hence,

Total Area Requirement

$$= \left[\sum_{y=1}^{y=n} Ay + 1.5 \times Xn \right] \times [Max(Bzn) + 1.5]$$

Where, Xn= No. of Machines, Ay= Machine Width, B_z= Machine Length

1.5 is minimum distance need to keep on machine side for machine maintenance purpose

*Inventory to be added as per process requirement between two machines

Space requirement for Store

For Store area calculation 'Planning For Each Part' (PFEP) sheet is effective tool. In this Store is divided in to three stages-

On Floor Storage-

It includes Cylinder Head, Cylinder Block, flywheel etc.

$$\text{Area required Part Storage on Floor} = \frac{[(L \times W) \times NP]}{SL}$$

Where, L = Length of Primary Pack, W = Width of Primary Pack, NP = No. of Packs required as per inventory norms,

SL = Staking Levels for Part Storage

No. of Packs required as per inventory norm is calculated as below-

$$NP = \frac{\text{No. of parts required to keep as per inventory norms}}{\text{No. of parts per primary pack}}$$

High Bay(HB) Rack Storage-

It includes A & B Class Items

$$\text{Area required for part storage on HB Rack} = N_{HB} \times A_{HB}$$

Where,

N_{HB} = No. of High Bay Rack Modules required

A_{HB} = Area required for one High Bay Rack Module

Area occupied by one High Bay Rack Module is (Length=2.5meter X Width=2.6meter) 6.5sq.meter

In one High Bay Rack Module, there are eight plastic pallet locations. Capacity of one pallet location is (1.2M*1M*1.5M) 1.8cubic meter

For Calculating No. of High Bay Rack Modules required (N_{HB}), we need to calculate total no. of pallet locations required to store total no. of primary packs.

$$N_{HB} = \frac{\text{Number of Pallet Locations Required}}{8}$$

No. of pallet locations required for one parts are calculated as given below:

$$= \frac{\text{Volume of one primary pack} * NP}{\text{Capacity of one pallet location}}$$

Where,

NP = No. of Packs required as per inventory norms

$$NP = \frac{\text{No. of parts required to keep as per inventory norms}}{\text{No. of parts per primary pack}}$$

Market Place Rack Storage-

It includes C & D category parts.

Area required for part storage on MP Rack= $N_{MP} * A_{MP}$

Where, N_{MP} = No. of Market Place Rack Modules required,
 A_{MP} = Area required for one Market Place Rack Module

Area occupied by one Market Place Rack Module is (Length=2meter X Width=1.3 meter) 2.6sq.meter

As C & D Class parts will come in various packaging sizes, to avoid complexity in calculation, we need to take average packaging size. After Studying PFEP average size of packaging is taken as 0.6meter x 0.4meter x 0.22 meter, which is near to plastic crate size. One Market Place Rack capacity is standardize for 24 plastic crate of above size. Therefore Total number of market place racks required are calculated as given below:

No. of Market Place Racks Module

$$N_{MP} = \frac{\text{No. of plastic crates required}}{24}$$

No. of plastic crates required = No. of Packs required as per inventory norms (NP)

$$\text{Hence, } N_{MP} = \frac{NP}{24}$$

Where, NP = No. of Packs required as per inventory norms

$$NP = \frac{\text{No. of parts required to keep as per inventory norms}}{\text{No. of parts per primary pack}}$$

Advantages of Plan For Every Part (PFEP) for Area Calculations:

With the help of above calculation we have completed PEPF for each project. It helped in following:

1. Total area required for each project
2. Storage location identification for each and every part.
3. Storage facility requirement for every project
4. Material handling equipment requirement
5. Flow of material inside plant.
6. Help in detailed calculation for utilization of each resource in stores
7. Material scheduling and controlling

PFEP result after detailed calculation is given below:

TABLE 1: Area Calculation for Stores

Sr. No.	Facility	Summary of PEEP For S101	Empty Storage Area @ 25%	Area For Variants @ 20%	Total Area
1	On floor	461	115	115	691
2	Market Place Rack	714	179	179	1072
3	High bay rack	983	246	246	1475
Total area in Sq Meter					3237

Earlier area requirement for S101 store was 4979 Sq. Meter. Final area requirement was 3237 Sq. Meter. We have achieved 34% storage area reduction through detailed calculation of PFEP

Alternative Layout Plan evaluation

There layout options were prepared considering above space calculation and Flow analysis.

Number of service department and operating department are summarized in table given below:

TABLE 2: List of MHEPL S101 Engine plant Department

Sr No	Department	Group number
1	Assembly Line and Testing	1
2	Head line And Block Line	2
3	Store	3
4	Engine PDI and Dispatch	4
5	Engine assembly and testing Rework room	5
6	Incoming inspection area	6
7	Rejection area	7
8	Equipment charging area	8
9	Warranty area	9
10	EN room	10
11	Project Room	11
12	CMM room	12
13	QCRT room	13
14	Scrap area	14

Relationship between department is mapped through “A, E, I, O and U” chart

TABLE 3. AEIOU Chart

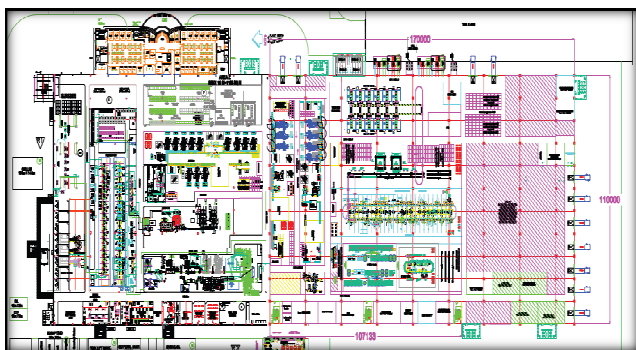
Value	Closeness	Line code
A	Absolutely Necessary	=====
E	Especially Important	=====
I	Important	=====
O	ordinary closeness OK	=====
U	Unimportant	
X	Undesirable	~~~~~

		7		6
8	==	3	=====	14
2	=====	1	=====	4
				~~~~~
12		5		9
10		11		13

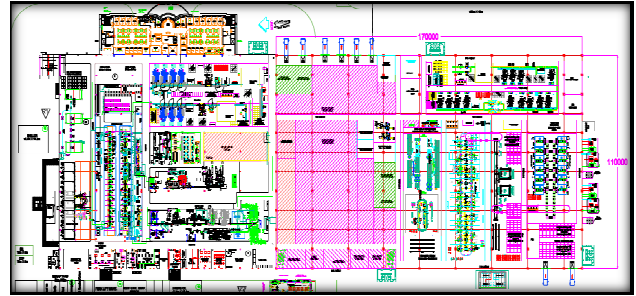
**Fig. 4. AEIOU chart for S101 Engine Plant**

Relationship between S101 Engine shop departments is mapped with reference to A E I O U chart.

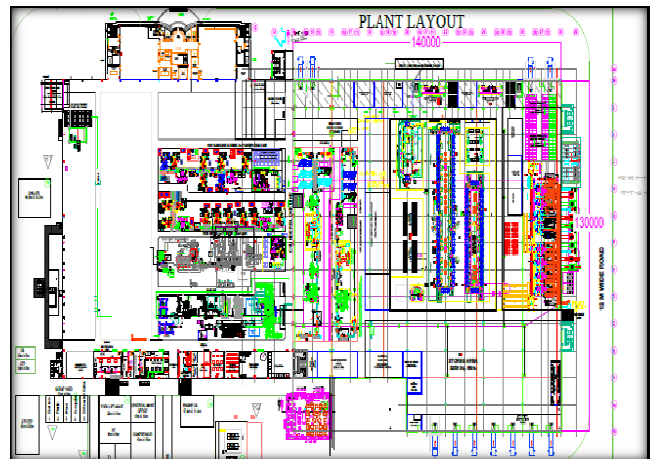
Based upon AEIOU chart many layout options prepared.



**Fig. 5. S101 Engine Layout option no. 1**



**Fig. 6. S101 Engine Layout option no. 2**



**Fig. 7. S101 Engine Layout option no. 3**

Factor comparison (refer Table 7) method used for comparing three feasible options:

**TABLE 4: Factor comparison method for layout selection**

Sr. No.	Factors	Wt.	Alternative Layouts		
			Option 1	Option 2	Option 3
1	Ease of future expansion	7	28	7	28
2	Flexibility of layout	3	6	6	6
3	Flow of material effectiveness	8	8	8	24
4	Material Handling effectiveness	7	21	7	21
5	Storage effectiveness	8	16	16	32
6	Space utilisation	8	16	16	16
7	Safety and housekeeping	10	20	20	20
8	Ease of Supervision and control	6	18	12	24
9	Utilisation of natural conditions or Surroundings	7	21	14	28
Total Score			154	106	199

Layout option number 3 selected for implementation of S101 Engine manufacturing facilities.

### 3. CONCLUSION

1. Systematic layout planning (SLP) technique helps in decision making for best feasible layout selection
2. SLP follows structured and analytic process
3. Optimum Storage space requirement can be calculated using SLP

4. SLP helps in material control and scheduling
5. SLP focus on least material handling in plant

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SECTION – V

MANUFACTURING TECHNOLOGIES

(CONVENTIONAL AND ADVANCED)

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# Synthesis and Evaluation of N/TiO₂ Nanoparticles for the Photocatalytic Degradation of Methylene Blue

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**Abstract:** The N/TiO₂ photocatalyst was prepared by ultra-sonication method for achieving enhanced visible light response. UV-Visible spectroscopy, field emission scanning electron microscopy and energy dispersive studies were carried out to characterise prepared N/TiO₂ nanoparticles. Compared with pure TiO₂, the N/TiO₂ photocatalyst exhibits red-shifts with improved light absorption capacity. Scanning electron microscopic observations reveal almost spherical morphology with relatively uniform sizes. The photocatalytic activity of prepared N/TiO₂ photocatalyst was evaluated by photo degradation of Methylene Blue (MB) under simulated solar radiation. The increased dye degradation efficiency of N/TiO₂ photocatalyst may be attributed to the enhanced visible light absorption for photoexcitation and charge separation efficiency.

**Keywords:** semiconductor, nanoparticles, ultra-sonication, heterogeneous photocatalysis, visible light

## 1. INTRODUCTION

Transition metal oxides are most commonly used for photocatalytic applications (Marschall and Wang, 2014). TiO₂ is a wide band gap non-toxic semiconductor photocatalyst with high chemical stability and low cost. However, pure TiO₂ limits its application to the UV part of the solar spectrum. Thus, only small part of the solar energy (~5%) utilized efficiently (Fang, Xing and Zhang, 2017; Khedr et al., 2017). Therefore, it is essential to shift the absorption edge of solar spectrum to the visible region and reduce the recombination of electron-hole (e⁻/h⁺) pairs to enhance the photocatalytic activity of TiO₂. Different modification techniques have been adopted for the effective modification of TiO₂ including non-metal or metal doping, noble metal deposition, semiconductor coupling, carbon-based composite etc. (Hernandez et al., 2017; Shifu et al., 2005). Physical dimension of the materials significantly influence their properties and applications (Michael and Hochella, 2002). Nitrogen doped TiO₂ nanoparticles are proved to be efficient for achieving enhanced photocatalytic performance including photodegradation of organic compounds (Dolat et al., 2015; Devi, Nagaraj and Rajashekhar, 2012) and hydrogen generation from water splitting (Wang et al., 2013; Villa et al., 2012; Naik et al., 2015).

Printing and dyeing wastewater mainly contains complex carcinogenic organic compounds with poor biodegradability (Chen et al., 2017). Photocatalysis could completely degrade organic pollutants into CO₂, H₂O and other mineral acids (Shifu et al., 2007). In addition to that, photocatalytic degradation of industrial effluents is a facile and environmental friendly technology and has developed rapidly in recent years (Yang et al., 2015). In the present

work, Nitrogen doped TiO₂ has been prepared via ultrasonication method and utilised for the effective degradation of methylene blue (MB).

## 2. METHODOLOGY

### 2.1 Materials

Commercial P25 TiO₂ (Evonik, Germany) with BET surface area of 50.68 m²/g was used as photocatalysts. Urea was purchased from Merck. Methylene blue was obtained from LOBAL Chemie. All the reagents were of analytical grade and were used without further purification.

### 2.2. Synthesis of Nitrogen Doped TiO₂ (N/TiO₂)

3 g of TiO₂ nanoparticles were mixed with 6 g of urea in 10 ml of distilled water. The prepared solution was then sonicated for 2 h at 37 KHz. Finally, the sonicated solution was filtered and dried in a hot air oven for 1 h at 100 °C and calcined at 400 °C for ½ h in the muffle furnace with air.

### 2.3. Characterization of Photocatalyst

The absorption spectra N/TiO₂ was recorded with UV-Visible spectrophotometer (Agilent Cary 5000). The morphology and structure of the particles were observed using a field emission scanning electron microscopy (Supra 55 Carl Zeiss Germany). The compositions of the prepared photocatalyst were measured by energy dispersive spectrometry (EDS).

### 2.4. Photocatalytic Activity Evaluation

The photocatalytic activity of prepared N/TiO₂ samples was evaluated by monitoring the photodegradation of methylene blue (MB) in aqueous solution. A 300 W solar lamp was



used as light source and UV-Visible spectrophotometer (Evolution 300 UV-Vis, Thermofisher Scientific) was used for the photocatalytic activity measurements. 0.5 g N/TiO₂ powder was added into a 250 ml of 50 mg/L MB solution. The solution was stirred continuously at 500 rpm by magnetic stirrer in dark for 60 min. for the powder to absorb the MB solution and reach absorption desorption equilibrium. At the end of first 60 min, a sample of 5ml was taken from the suspension by means of syringe filters (0.22 µm) for spectrophotometer measurements. After the first measurement, the solar lamp was turned on and changes in absorbance under simulated solar radiation were measured after every 60 min till 3 hours of continuous irradiation and stirring.

### 3. RESULTS

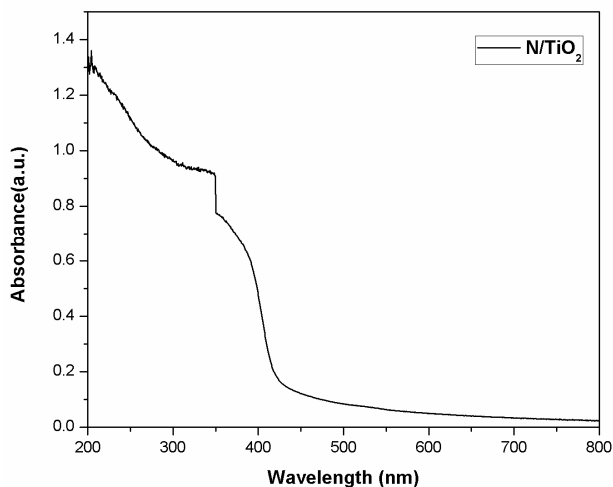
#### 3.1 Effect of Nitrogen as Co-catalyst

The enhancement of the photocatalytic performance N/TiO₂ was attributed to the enhanced photogenerated electron-hole separation efficiency and the advanced absorption of light. The successful doping of cocatalyst introduces additional energy level in the primary catalyst reducing the band gap of the prepared nanocomposite(Kuvarega, Krause and Mamba, 2015).

#### 3.2 Characteristics of Photocatalyst

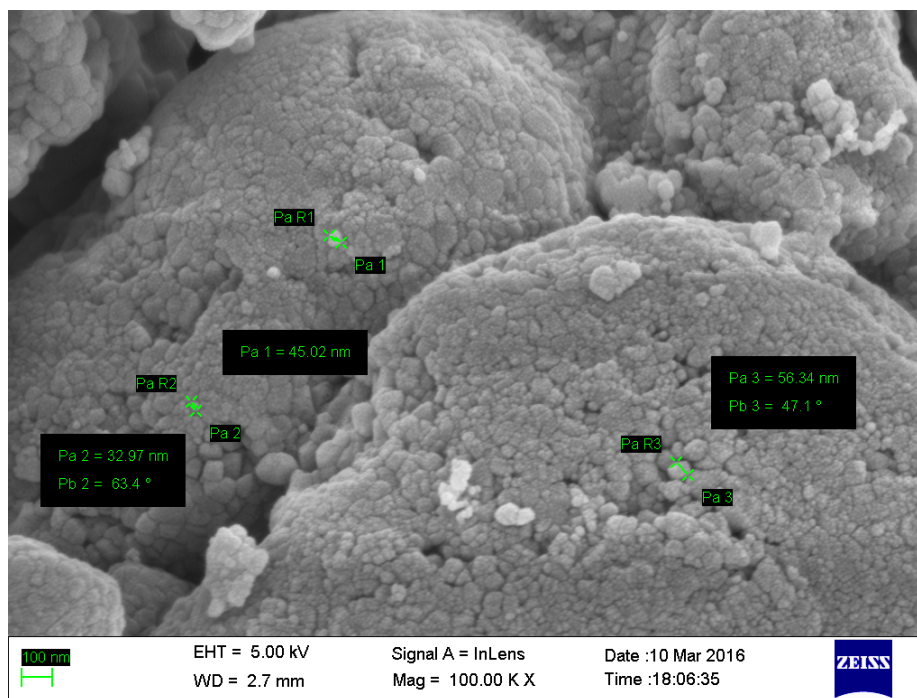
Fig. 1 shows the UV–visible absorption spectra of the N/TiO₂ nanoparticles prepared by ultra-sonication method.

The absorption spectra were scanned from 200 to 800 nm to determine the optical properties of the prepared photocatalyst. Band gap of the prepared nitrogen doped TiO₂ semiconductor photocatalyst was calculated to be 2.82 eV.



**Fig. 1. UV–visible absorption spectra of the prepared N/TiO₂ nanoparticles**

Observations by FESEM revealed that all the samples have almost spherical shape with certain agglomeration tendency and size in nano range as shown in Fig.2.



**Fig. 2. FESEM image of the prepared N/TiO₂ nanoparticles**

EDS spectra shown in Fig. 3 confirmed the presence of nitrogen on the surface of TiO₂ nanoparticles. EDS was employed to detect elemental compositions of the prepared photocatalyst.

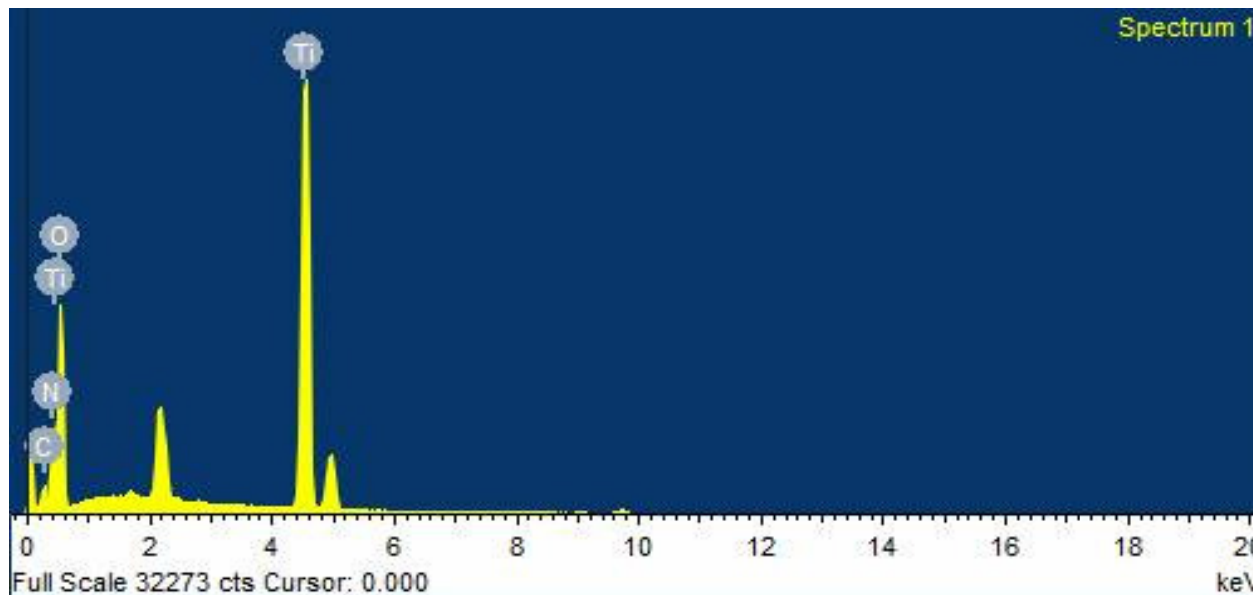


Fig. 3. EDS spectra of the prepared N/TiO₂ nanoparticles

### 3.3 Photocatalytic Degradation of Methylene Blue (MB) Solution

Methylene Blue (MB) was used as a model dye to estimate the photocatalytic activity of prepared N/TiO₂ sample under simulated solar radiation. The photocatalytic degradation efficiency illustrated in Fig. 4 was calculated by using the following equation.

$$\text{Degradation Efficiency (\%)} = \frac{C_0 - C_t}{C_0} \times 100\% \quad (\text{i})$$

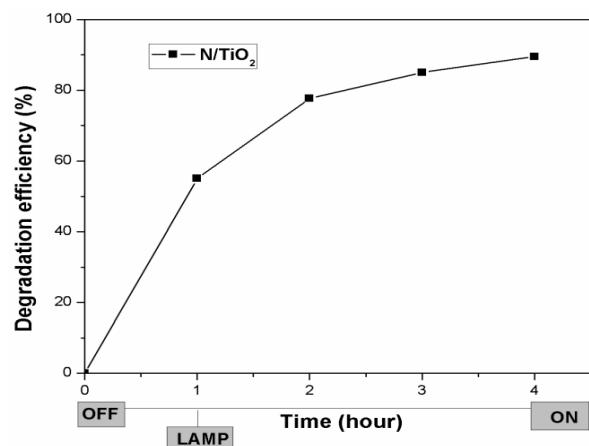
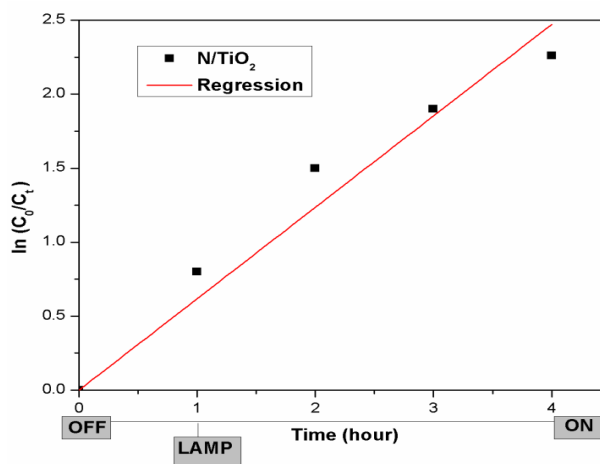


Fig. 4. Photocatalytic degradation efficiency of MB under simulated solar irradiation

The kinetics of MB photodegradation on the photocatalyst surface can be described by the first-order reaction

$$\ln \frac{C_0}{C_t} = kt \quad (\text{ii})$$

Where,  $k$  is the rate constant ( $\text{min}^{-1}$ ),  $C_0$  is the initial concentration of MB and  $C_t$  is the concentration of MB at the irradiation time ( $t$ ). Fig.5 describes the linear relationship of  $\ln(C_0/C_t)$  versus irradiation time ( $t$ ). Rate constant ( $k$ ) was determined for N/TiO₂ photocatalyst from the slope of linear fitting line as shown in Fig. 5. As it can be seen, a good correlation to the first order reaction kinetics ( $r^2 > 0.95$ ) was found.



**Fig.5. Kinetic data for the degradation of aqueous MB under simulated solar irradiation**

#### 4. CONCLUSION

Nitrogen doped TiO₂ prepared via ultra-sonication process exhibits almost spherical morphology with the band gap of 2.82 eV. According to dye degradation experiment results, the reaction followed first order kinetics and prepared N/TiO₂ catalyst shows high photoactivity. The enhanced dye degradation efficiency of N/TiO₂ photocatalyst may be attributed to the enhanced visible light absorption for photoexcitation and charge separation efficiency.

#### ACKNOWLEDGEMENTS

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# A Review on Simulation of Different Process Parameters in Metal Casting and Prediction of Porosity Formation

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**Abstract:** There are many works has been done on the formation of porosity in the metal casting, but formation mechanism is still not clear. How to decrease the porosity formation cannot be identified and thus it's a main issue in industries. The part rejection in industry up to 40 to 50 % is due to porosity formation in parts either on inner or outer surface. This review paper study many previous works on metal casting porosity formation identified in different parameters, they are depending on porosity formation like mould filling, solidification (melt state change, pore nucleation and pore growth) these are effective parameter during solidification stage. This review paper gives convectional explanation for the prediction of porosity formation using simulation software.

**Keyword:** mechanism, parameter: solidification, moulding filling, heat transfer, feeding flow, simulation, porosity.

## 1. INTRODUCTION

Although many works [Campbell et al., 2015; Vijayaram, 2009] were reported on porosity prediction in ductile material like aluminium, steel and iron but their formation mechanism is still not clear. The porosity is classified into shrinkage porosity and gas porosity but the shrinkage porosity is rare in casting. Most of the casting scrap is assigned as shrinkage porosity. When we observe regions of apparent shrinkage porosity on a radiograph, the oxide bifilms and air bubble arises from the scrambled mess, these are convincing appearance of shrinkage. Generally shrinkage behaviour in the molten metal in furnace occupies considerable more volume than the solid volume of casting. While solidification of molten metal the contraction/shrinkage occurs at three stages as follows

1. First is the liquid contraction also called thermal contraction, the temperature reduces, the volume of the moulded metal reduces almost linearly to compensate falling temperature at this stage liquid metal reduced to compensate for small reduction in volume as show in figure 1, at this stage there is no considerable formation of porosity.

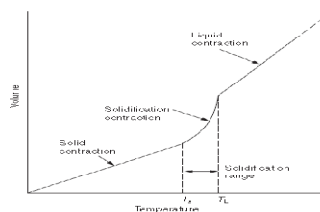


Fig. 1. Different Type of Contraction [Campbell et al., 2015]

2. Second stage is Solidification Contraction. It occurs at freezing point and after at that point reduced temperature. This is the stage where molten metal starts getting solidify thus the density difference among molten metal occurs as show in figure1, so there is more chance of formation of porosity, at the same time solidification contraction started, this contraction causes several problems. If the feeding of molten metal done at solidification stage then the shrinkage porosity formation is greater, the reason behind this is failure of operating of feeding device.
3. The final stage of shrinkage in the solid stage. Almost cooling and solidification is completed and form the predetermined object.

Another type of porosity is gas porosity and affecting parameters are as follows-

1. From air bubble during turbulent pouring.
2. From core blows on chills.
3. From perception of gas in solution in the metal.

## 2. LITERATURE REVIEW

Marek Bruna et al done advance calculation for the prediction of porosity formation for aluminium alloy by advance porosity module included in ProCAST software. In experiment he used thermal analysis to get accurate data about used alloy [marekbruna, 2017].

In this paper the riser size of the aluminium alloys is optimized by using conventional method and AutoCAST simulation software. Work on fluid flow

interdendritic driven on shrinkage and gas porosity help of the chills place on plate at end of chills effect, centre chills effect identify solidification time of casting [Zhao and Liu, 2007].

H. D. Zhao et al based on the model of microstructure formation of SGI casting, a method was proposed to calculate the feeding flow and to predict the macro porosity during solidification of the castings. The simulation results clearly indicated feeding relationship between feeding system and casting body. With the calculation feeding flow, it may be judged and investigated whether an isolated liquid and mushy region expands or contracts [Paine et al., 2002].

The simulation technology has sufficient to prediction of the porosity formation. This paper work on the mould filling simulation of casting process porosity formation. Comparisons of feeding from risers with and without insulating sleeves. The metal in the riser without sleeves shows piping, whereas the metal in the riser containing an insulating sleeve does not show piping. The liquid in the insulating sleeve moves down horizontally and has a large influence on lowering the total level of micro-porosity in the casting [Niels Skat et al., 2013].

Kulkarni et al., 2011, find out the heat transfer during solidification of commercial available Al-4.5% Cu alloy casting CO₂-sand mould was assessed using an inverse analysis technique. The casting/mould interfacial heat flux and the peak heat flux represented the maximum heat transfer from the casting to CO₂-sand mould. The time of occurrence of the peak heat flux transients was nearly five seconds after pouring. During this processing porosity formation can be minimized [Kulkarni, 2011].

### 3. MECHANISM OF POROSITY FORMATION

It seems that porosity formation mechanism has not been cleared so far. The authors propose the following mechanism.

**Mould filling stage-** The mould filling stage should be added, because gas and non-metallic inclusions are entrapped during mould filling and play an important role as nuclei for porosity defects as well as for effective risers [Paine et al., 2002].

**Melt state change -** The melt pressure decreases with solidification because the outer part of casting solidifies first and expands while the inner part cannot expand because of less graphite formation there. The pressure decrease varies with shape and size of castings. The undercooling and mould wall expansion due to melt head can assist this phenomenon. Further, the super saturation of gaseous elements can occur when the concentration of gaseous elements is high. With this pressure decreasing the melt is sucked from risers or other parts where solidification delays and the melt can move. When the outside of risers has

solidified and has no pores, the melt is difficult to move, resulting in more pressure decrease. The effect of inoculation is thought to increase the fluidity of the mushy region.

Although Rivera et al. [30] reported that inoculation was not so effective to nodule grain refining, grains become a bit smaller. If the grains are smaller and, in particular, rounder, the fluidity of the mushy region should be improved, resulting in less pressure decrease and less porosity. The reason why grey iron tends to have much less porosity defects are due to the fact that graphite grows into the melt causing melt pressure increase rather than solidified shell expansion. Further, because grey iron solidifies with skin formation type, the melt is the easily sucked preventing the pressure decrease. In the case of hypoeutectic ductile cast iron, its more connected dendrite network hinders the melt flow, resulting in more porosity defects [Sabau, 2002].

**Pore nucleation-** Pores nucleate, when the pressure in the melt decreases below a critical value, depending on the super saturation and existence of pore nuclei. The most important nuclei maybe the gas bubbles entrapped during mould filling. The authors observed gas entrapment in all castings with X-ray. The gas component can be hydrogen when the mould is green sand mould. However, because we do not have enough data on the gas component in pores, it should be more examined.

The opposite estimation results obtained by the stress analysis by the effect of the gas bubbles entrapped during mould filling compares the mould filling difference of the two castings, the melt in the casting (flows first to the central part and collides in the side cavity, while the flow in the casting fills the cavity smoothly and the melt collides in the riser.

Namely, gas entrapment in the casting is estimated to be less, resulting in fewer nucleuses for pore defects and more bubbles in the riser make the feeding easier from the riser. It is possible that if slag such as Mg₂SiO₄ and 2FeO.SiO₂ generated by the melt treatment is entrapped; CO gas can be generated with the reaction of carbon in the melt [Ohnaka, 2007].

**Pore growth -** The pores grow further with decreasing melt pressure or increasing super saturation of gaseous elements [Campbell, 2005].

**Final state-** The pressure decrease stops and begins to increase when graphite formation rate becomes larger than in the outer part of the casting. The increase in pressure makes the pore smaller but hard to completely eliminate, because it requires very high pressure to resolve the gas pore once formed. Further, the segregation of Al-alloy and Mn and others causes cementite solidification resulting in micro porosity [Sanjuam, 2005].

#### 4. EFFECT OF PARAMETER ON POROSITY FORMATION

The porosity formation in metal casting process is still not identify specific parameter to decreasing porosity formation many stage of the casting process parameter is the effect on porosity formation, this review paper different parameter identifies to the casting process and prediction porosity formation.

**Mould filling-** The Mould filling simulation is prediction of most common problem during filling of molten metal into die these stages atmospheric oxide entrapment occurs largely as a result of turbulence flow, its oxide get pulled into the liquid cavity due to generation of porosity. high turbulence flow is caused due to starting of the flow of basin not fill completely then partial flow of the pour, excessive flow velocities, irregularities in the component geometry, bad pour and gating design, insufficient venting this parameter preventing too difficult to fill without creating turbulence using standard gravity methods and it may mean that the process needs to be changed in order to prevent turbulence [NielsSkat et al., 2010].

To determine the optimal rotational speeds at each stage in the pouring process, in order to maintain an acceptable filling velocity, quite difficult without being able to visualise actually happens to the liquid during filling. Simulation provided information about the liquid flow behaviour during pouring and different rotational speeds to find the optimal condition. Sections that require extra venting can easily be identified and modified to prevent incomplete filling. Approach in finite element modelling (developed by Ch. Piquet and M. Rappaz3) is to use a mesh refinement technique in the mushy zone, which enables the prediction of porosity on a micro scale. In order to simulate porosity and study the effects of gas content, alloying elements, feeding behaviour and pressure on porosity, it isEssential to consider all the physics which govern the formation and growth of pores. The pressure drops in the mushy zone, gas segregation in the liquid and the nucleation and growth of pores needs to be considered to accurately model the formation of porosity [Paine et al., 2002].

**Heat transfer rate-** The heat transfer rate at the at the casting and mould interfere play import role to determining temperature gradient in the solidification of casting, during solidification of the casting controlling factor due to the fact that offering largest resistance to heat transfer flow out into casting into metallic mould is low and the alloy of long freezing range are particular to a type of porosity formation that is observed to generate in layer porosity this condition favourable to formation of porosity indicate to wide range a arising from long freezing time and poor temperature gradients, poor temperature gradient is typical of the alloys

of high thermal conductivity and mould having low rate of heat transfer.

By using simulation software prediction of porosity formation preventing to this problem, previous experimental work on this area its using chills ty to heat transfer rate increasing inner to outer side. Consider the different parameter the simulation made using software procast. Tis software solves the conversation equation using finite element method. This experiment repeats two times first one without chills and second one with six chills compare second result is less porosity formation [Liu et al., 2017].

**Feeding flow-** During the solidification of a casting, the gradual spread and growth of the solid, often in the form of a tangled mass of dendrites, presents increasing difficulties for the passage of feeding liquid. In fact, as the freezing liquid contracts to form the solid, the pressure in the liquid falls, causing an increasing pressure difference between the inside and the outside, generally five types of feeding occurs in casting process like liquid feeding, mass feeding, interdendritic feeding, burst feeding, solid feeding, they assess only the difficulty of interdendritic feeding, they apply best to strong materials such as steels in relatively cold moulds. Here, interdendritic feeding can become impossibly difficult, generating high internal tension in the casting, a condition that the computer would interpret as leading to porosity. However, in conditions in which the solid is softer and can yield plastically, the mould can collapse slightly to give an internally sound casting. Such conditions apply, for instance, in steels cast into hot investment moulds and light alloys in cold moulds where significant solid feeding can occur, causing the criteria function to become inaccurate [Zhao, 2007; Steinbach, 2009]

Criteria functions cannot predict conditions for porosity arising because of the many other mechanisms to produce porosity in castings. These include the major shrinkage pores because of the isolation of major liquid regions, the creation of surface-initiated porosity and the mechanically entrained porosity originating from bubbles of air and mould gases introduced by poor filling systems. Experience shows that in general entrainment defects cause most of the porosity found in casting. Shrinkage porosity is quite rare because, as we have noted previously, founders understand shrinkage and can avoid it. In fact, the ability to avoid shrinkage problems is continuously improving now because of the continuous development of prediction using computer models [Zhao, 2007].

**Solidification contraction -** In general liquids contract on freezing because of the rearrangement of atoms in the liquid structure changes from a rather open 'random close-packed' arrangement to a regular crystalline array of significantly. The densest solids are those that have close-packed face

centred cubic (fcc) and hexagonal close packed (hcp) symmetry. Thus the greatest values for contraction on solidification are seen for these metals. The contractions are in the range of 3.2–7.2%. The solidification shrinkage for the less closely packed body-centred cubic (bcc) lattice is in the range 2–3.2%. Other materials that is less dense in the solid-state contract by even smaller amounts on freezing [Sabau, 2002].

The liquid contraction in casting is the decreasing same volume of molten metal is fill without difficulty but during solid contraction of the metal casting process is very difficult fill solid shrinkage [Campbell, 2015]. The final integrity of a casting is greatly influenced by presence of the porosity, the progressive way to predict presence of porosity is the use of present time modern simulation program. These previous work using thermocouple were placed in different places at the mould for measuring thermal analysis data during experiment and created in proCAST simulation is identify two points is namely coherency Point and rigidity point are also suggested to related with porosity formation during solidification process [Campbell, 2015, Zhao, 2007]. The rigidity point is the solid fraction at which the dendrite structure of solidifying alloy because it mechanically rigid, the rigidity point al-alloys approximate 89 % solid at temperature 561.84°C and 2) The coherency point low solid fraction up to (0-20 %) there is no difficulty feeding of molten metal and coherency point occurs at 17.43 % solid of al-alloys at temperature 607.93°C [marekbruna, 2017].

## 5. POROSITY PREDICTION USING SIMULATION

The computer simulation of casting use different type defects predicted but most common defect on the casting is a porosity due generated porosity formation like mould filling, solidification, feeding is predicted to simulation software. All of the parameter solidification of metal and al-alloys is a complex phenomenon related to these problem made simulation of solidification process is done by running indigenously developed computer software for the metal [marekbruna, 2017].

In the casting process, the program output parameter provided details on time-temperature profile and heat transfer coefficient values they play an important role in the effective design of casting

The aim of simulation of the casting is as follows

1. Predict the pattern of solidification, indicating shrinkage cavities and associated defects may be arises.
2. With simulation the best position selected from various position of casting.

3. Simulation also calculates the change of volume during solidification and weight of the different material in the solid state.
4. Simulation also provides a choice of quality level of casting, for example ignoring of micro porosity [Vijayaram, 2009].

## 6. CONCLUSION

The study of the different type of process parameter and predict porosity formation using casting simulation has become a powerful tool to predict the porosity generation and eliminate them by visualizing mould filling, solidification and cooling rate of the casting and thus it becomes easy to identify the affecting factors of the porosity formation. Decrease in pressure caused by non-uniform solidification and gas bubbles entrapped during mould filling play key role of the formation of porosity. Using simulation by controlling pressure, gases entrapped in casting and reaction of metal helps to minimize of the porosity formation.

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# Optimisation of Machining Parameters using TOPSIS-Based Taguchi Approach for Turning of AISI D2 Steel

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**Abstract:** The present study highlights in order to examine the different turning parameters such as spindle speed (N), feed rate (f) and depth of cut (d) on different performance measures during dry turning of AISI D2 Steel using PVD coated carbide tool. Experiments has been conducted according to L9 orthogonal array in order to assess the turning performance characteristics such as material removal rate (MRR) and surface roughness (Ra). Attempt was further made to convert the multi responses into equivalent single response i.e. TOPSIS. In this study, Decision-Makers' (DMs') subjective opinion (in regards of response weight) expressed in linguistic terminology has been transformed into appropriate fuzzy numbers. Fuzzy representation of multiple-judgments have been aggregated and finally defuzzified to obtain crisp weight. Response data thus obtained from machining experiments along with crisp weight of the responses have been utilized in TOPSIS. Finally Taguchi has been implemented in order to determine the optimal parametric combination.

**Keywords:** TOPSIS-based Taguchi approach; AISI D2 steel

## 1. INTRODUCTION

Nowadays, hard turning technology has made tremendous growth and advances in manufacturing industries in order to manufacture of many high precision, high hardness components. AISI D2 steel have been commonly applied in the long run tooling applications, where wear resistance is important, such as blanking or forming dies and thread rolling dies. Hence, it became essential to understand the machinability aspects of these materials.

Kishawy and Elbestawi examined the effect of machining parameters such as cutting speed, feed rate and depth of cut in turning of AISI D2 steel using PCBN tools. They concluded that cutting speeds above 350 m/min, the surface roughness increased with increase in tool wear and this was attributed to material side flow. Konig et al. 1984 noticed that application of PCBN tools in machining of hardened steels improves tool life values as compared to ceramic tools. Aouici et al. (2014) applied RSM and desirability function approach in order to evaluate the optimal process parameter in the turning of AISI D3 steel. Ferreira et al. 2016 done the experimental investigation on the turning of AISI H13 steel with ceramic tools: conventional and wiper. It has been observed that wiper tool reduces the flank wear.

In this paper, TOPSIS coupled with Taguchi philosophy Hwang and Yoon 1981, Lan 2009 has been proposed for optimizing multiple performance characteristics such as material removal rate and surface roughness.

## 2. MATERIAL EXPERIMENTATION

The study analyzed the effect of machining variables such as spindle speed, feed rate and depth of cut in turning of AISI D2 steel. The machining variables are varied into three different levels which is shown in Table I.

**TABLE 1: Domain of Experiment**

Sl. No.	Process parameters	Level (1)	Level (2)	Level (3)
1	Spindle Speed (N)	420	605	787
2	Feed Rate (f)	0.05	0.06	0.07
3	Depth of Cut (d)	2	2.5	3

A series of experiments have been carried out on manually operated lathe (Specification of lathe)) in order to obtain the experimental data. So, proper design of experiments has been essential for experimentation. Therefore, Taguchi has been implemented in order to decide the number of experiments. Here, L9 orthogonal (Table II) array has been selected for conduction of experiments. Cemented carbide too has been used for turning operation. Material removal rate and surface roughness have been evaluated as the machining evaluation characteristics. Following is the equation that has been used to determine the material removal rate.

The surface roughness has been evaluated by a surface roughness tester (Talysurf). Table II shows the experimental results.

**TABLE 2: Design of Experiment (L9 Orthogonal Array) and experimental data**

Sl. No.	N	f	d	MRR [mm3/min]	Ra [ $\mu$ m]
1	257	1.5	0.5	1087.386	3.87
2	257	2	1	803.3234	2.92
3	257	2.5	1.5	637.5	2.46
4	386	1.5	1	1256.97	4.35
5	386	2	1.5	923.789	3.81
6	386	2.5	0.5	708.434	2.16
7	566	1.5	1.5	789.67	3.03
8	566	2	0.5	762.7177	2.66
9	566	2.5	1	1270.528	3.93

### 3. DATA ANALYSIS

For data analysis, data preprocessing i.e. normalization has been carried out (TOPSIS method). The normalized data have been shown in Table III.

**TABLE 3: Calculated normalized values**

Sl. No.	N-MRR)	N-Ra
1	0.384715	0.388243
2	0.284214	0.292938
3	0.225546	0.24679
4	0.444714	0.436398
5	0.326835	0.382224
6	0.250643	0.216694
7	0.279384	0.303974
8	0.269848	0.266855
9	0.44951	0.394263

To determine the priority weight of individual responses, this study has adopted seven linguistic terms i.e. Very High (VH), High (H), Moderate High (MH), Medium (M), Moderate Low (ML), Low (L), Very Low (VL) to collecting expert opinion. Linguistic weight has been transformed into appropriate fuzzy data as shown in Table IV. Subjective expert judgments in relation to response weights have been shown in Table V. Linguistic data translated into fuzzy numbers have been aggregated first (Table VI). The best non-fuzzy performance value (crisp) corresponding to each response has been utilized as crisp weight. The decision matrix has been normalized then and the normalized decision matrix has been shown in Table III. In the next step, the resulting weighted decision matrix has

been constructed (Table VII). Then, the positive-ideal solution (FPIS) and the negative-ideal solution (FNIS) i.e.  $A^+$  and  $A^-$ , respectively, have been determined as shown in Table VIII. The distance for each alternative with respect to positive and negative ideal solution have been computed and shown in Table IX.

**TABLE 4: Linguistic variables for assigning importance weight of each response**

Importance	Abbreviation	Fuzzy weight
Extremely Low	EL	(0, 0, 0.1)
Very Low	VL	(0, 0.1, 0.3)
Low	L	(0.1, 0.3, 0.5)
Medium	M	(0.3, 0.5, 0.7)
High	H	(0.5, 0.7, 0.9)
Very High	VH	(0.7, 0.9, 1)
Extremely High	EH	(0.9, 1, 1)

**TABLE 5: Importance of output responses as given by the Decision-Makers (DMs)**

Output responses	Decision-makers linguistic weight for the responses			
	DM1	DM2	DM3	DM4
MRR	H	H	VH	H
R _a	VH	EH	VH	VH

**TABLE 6: Fuzzy weights and corresponding crisp conversion**

Output responses	Fuzzy weight	Best Non fuzzy Performance value (BNP) Crisp-weight
MRR	(0.55, 0.75, 0.925)	0.725
R _a	(0.75, 0.925, 1)	0.891667

**TABLE 7: Weighted normalized fuzzy decision matrix**

Sl. No.	W-MRR	W-Ra
1	0.278918	0.346184
2	0.206055	0.261203
3	0.163521	0.220055
4	0.322417	0.389121
5	0.236955	0.340817
6	0.181716	0.193219
7	0.202553	0.271043
8	0.19564	0.237945
9	0.325895	0.351551

**TABLE 8: The ideal (best) and negative ideal (worst) solution**

S.No	The ideal (best) $A^+$	The negative ideal (worst) $A^-$
MRR	0.325895	0.163521
Ra	0.193218875	0.389121345

**TABLE 9: Calculated distance measures**

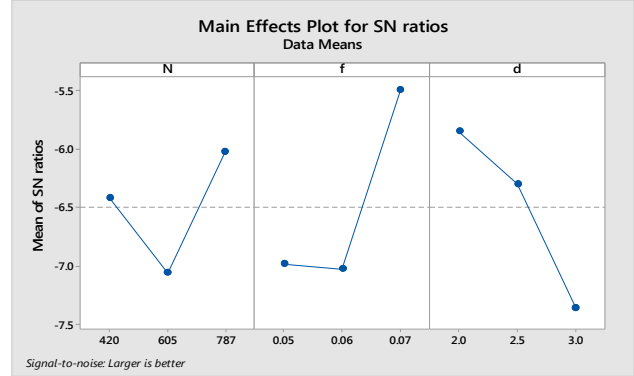
Sl. No.	$S_i^+$	$S_i^-$
1	0.160016	0.123127
2	0.13778	0.134804
3	0.164577	0.169066
4	0.195933	0.158896
5	0.172323	0.087897
6	0.144179	0.196745
7	0.145842	0.124362
8	0.13772	0.15455
9	0.158332	0.166664

After calculating the distance measures, the closeness coefficient has been calculated, and shown in Table X.

**TABLE 10: Closeness coefficients**

Sl. No.	$CC_i$	SNRA	P-SNRA
1	0.434858	-7.23306	-4.36392
2	0.494541	-6.11596	
3	0.506728	-5.90450	
4	0.447810	-6.97812	
5	0.337779	-9.42734	
6	0.577094	-4.77508	
7	0.460253	-6.74007	
8	0.528791	-5.53432	
9	0.512818	-5.80073	

The alternative with the largest relative closeness has been treated as the best choice. The best preference has been determined for the trial no. 12 by Taguchi method. The analysis has been carried out by Minitab software package using Higher-the-Better (HB) criterion. The predicted S/N ratio for the optimal parametric combination ( $N_3 f_3 d_1$ ) (shown in fig. 1) is -4.36392 which is highest among all the computed S/N ratios. Table X, that authenticates the applicability of the proposed TOPSIS based Taguchi method.



**Fig. 1. Evaluation of optimal setting**

#### 4. CONCLUSION

The analysis in this paper exposes that Taguchi's quadratic loss function with Fuzzy TOPSIS to solve the multi response surface roughness characteristics. The taguchi method deals with one dimensional problem and Fuzzy TOPSIS with multi dimensional problem and one performance measurement is required for the multiple responses at each experimental trial. Due to relation between the parameters parametric optimization is difficult to solve but the analysis in this paper demonstrate an optimization approach using orthogonal array and Fuzzy TOPSIS and sound perceptiveness.

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# Effect of Cryogenic Treatment on Hardness and Corrosion Resistance of Materials: A Review

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**Abstract:** Cryogenic Treatment is used for improving mechanical properties of material. This treatment can be done on components of IC engine, tools, components of Refrigeration and Air conditioning etc. In this paper mainly discuss about Material properties like hardness, strength, fracture toughness, wear resistance, corrosion resistance can be improve by cryogenic treatment as compared to other heat treatment process. Aerospace and tool industries use this treatment to improve the wear resistance, dimensional stability and other mechanical properties.

**Keywords:** cryogenic, deep cryogenic, shallow cryogenic, hardness, wear resistance, liquid nitrogen.

## 1. INTRODUCTION

Cryogenic Treatment is a cooling process carried out after the conventional heat treatment process. Two types of cryogenic process normally used are

- Deep Cryogenic Treatment and
- Shallow Cryogenic Treatment.

In Deep Cryogenic treatment, freezing chamber was maintained around  $-196^{\circ}\text{C}$ . In Shallow cryogenic treatment, freezing chamber was maintained around  $-80^{\circ}\text{C}$ . Treatment of Cryogenic process is carried out in the liquid nitrogen ( $\text{LN}_2$ ) chamber which was well insulated around it. After particular period cryogenic treated component is maintained at room temperature for further cooling.

In Deep Cryogenic Treatment, the high contraction of martensite structure occurs. This contraction forces carbon atoms to diffuse into micro cracks and dislocation sites, which are made during the conventional martensite transformation. Therefore, the fine carbides that improve the wear resistance of steel are formed during the tempering treatment [G Kumar et al., 2016].

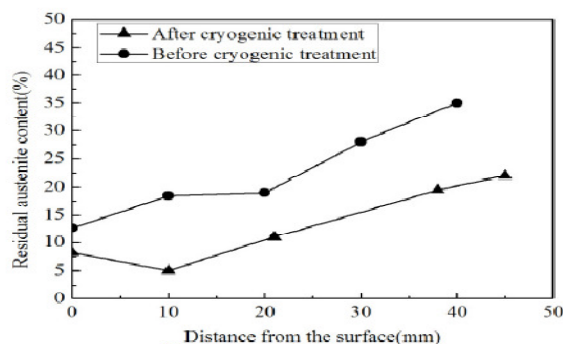


Fig. 1. the content of residual austenite [Guo Jia et al., 2014]

## 1.1 Process

Process of cryogenic treatment is as follows:

1. Component is cooled slowly with the help of liquid nitrogen to different temperature limits with different tolerance for particular period.
2. It soaked for that temperature more time due to this, the transformation of retained austenite to martensite occurs.
3. Then slow heating to room temperature [Vengatesh, 2016].

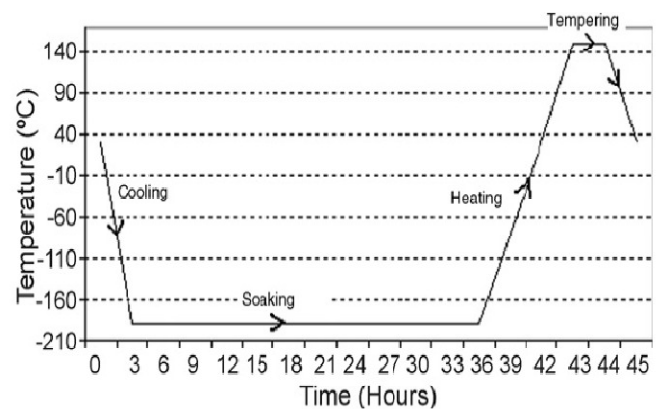


Fig. 2. Standard DCT cycle [Vengatesh, 2016].

## 1.2 Various types of Cryogenic treatment

### 1. Deep cryogenic Treatment

Deep cryogenic treatment is a less expensive process as compared with other, permanent treatment and to partake of changes to whole section of the component, unlike other treatment processes. The treatment is an add-on process to

conventional heat treatment process, in which samples are cooled from room temperature to  $-180^{\circ}\text{C}$  to  $-198^{\circ}\text{C}$  in 3.5 hr at  $1^{\circ}\text{C}/\text{min}$ , soaked at that temperature for 24-36 hrs, slowly heated back to room temperature. [G. Kumar, 2016]

## 2. Shallow Cryogenic Treatment

Shallow Cryogenic Treatment is similar process like deep cryogenic treatment process but only difference is samples are cooled from room temperature to  $-75^{\circ}\text{C}$  to  $-90^{\circ}\text{C}$  in 3.5 hr at  $1^{\circ}\text{C}/\text{min}$ , soaked at that temperature for 24 h, slowly heated back to room temperature. [Idayan, 2014]

Deep Cryogenic Treatment is mostly used than Shallow Cryogenic Treatment because of

- sum conversion of retained austenite in to martensite phase
- Increase in carbide density and their uniform distribution
- Precipitation of fine  $\eta$ -carbides
- The mechanism by which cryogenic treatment can improve the properties of steel is the formation of very small carbides dispersed in the tempered martensite structure. [Vengatesh, 2016]

## 2. LITERATURE SURVEY

G. Hemath Kumar et al., 2016 studied the cryogenic treatment on composite material of Automotive AC system. In this, paper he conclude deep cryogenic treated sample is better than untreated fabricated sample for all types of corrosion which is applicable in refrigeration system. There is an improvement in corrosion resistance of the material because of tight bonding between the grain structures of the material as compared with untreated fabricated composite material.

Guo Jia et al., 2014 studied cryogenic treatment on large rolls of rolling machine. In that he concluded that the most of the residual austenite would be changed into martensite after cryogenic treatment, which contributed to the improved hardness and dimensional stability.

M. Pérez et al., 2014 studied cryogenic treatment on forging die. concluded that cryogenics generate a high internal stress state that activate the carbide nucleation in the first phases of tempering, resulting in a much finer and evenly distributed precipitation which also give rise to a martensite with less carbon, so consequently tougher, at the end of the heat treatment.

A Akhbarizadeh et al., 2009 studied cryogenic treatment on D6 steel tool. It improves the wear rate of D6 compared with the non-cryogenically treated samples and also formation of the micro cracks and the reduction of the lattice distortion.

Rajesh and Hari Singh, 2009 studied the cryogenic treatment on Comparison of optimized settings for cryogenic-treated and normal D-3 steel on WEDM using grey relational theory. In this paper he concluded that the cryogenic treatment the Material Removal Rate decreases, Surface Roughness decreases of the work-piece. Cutting rate is not much affected.

Sanjeev Kumar et al., 2016 studied that Machining performance of cryogenically treated Ti-5Al-2.5Sn titanium alloy in electric discharge machining. The DCT of Ti-5Al-2.5Sn alloy significantly improves the MRR, TWR, SR, and microhardness during EDM in comparison to SCT of the same material which in turn shows improvements when compared to untreated material of the same alloy.

G Venses and R Sri Siva., 2015 studied the Optimisation of Deep Cryogenic Treatment Process on the Wear Resistance of 100Cr6 Bearing Steel. In this paper he explain that The most influencing factor for the improvement of wear resistance using the DCT was identified by the ANOVA as the soaking period.

Hasan et al., 2012 In this paper, effect of Cryogenic Treatment CBN inserts is studied. Cryogenically treated CBN inserts produced less tool wear on titanium than AISI 440 C Martensitic stainless steel and improves wear resistance.

## 3. EFFECT OF CRYOGENIC TREATMENT ON CORROSION RESISTANCE AND HARDNESS PARAMETERS

### 3.1 Corrosion Resistance

The corrosion rate for glass fibre polymer matrix composite material which is used in Automotive AC system untreated is 0.0098315 mm/year and composite deep cryogenic treated is 0.00371 mm/year. For impedance corrosion, the corrosion rate for composite untreated is 0.02715 mm/year and composite deep cryogenic treated is 0.01251 mm/year [G Kumar et al., 2016].

### 3.2 Hardness

Hardness of polymer metal matrix composite is increased from 245.67 HV of untreated component to 279.18 HV of deep cryogenic treated component [G Kumar et al., 2016].

The depth of hardened layer of large rolls used in rolling machine has been thicker and the hardness of the roll has been improved [Guo et al., 2014].

Hardness of AISI 440C Bearing Steel for Raw Material is 20 HRC, Convectional heat treatment process is 57 HRC, Shallow Cryogenic treatment is 59 HRC, and Deep Cryogenic Treatment process is 61HRC.[ Idayan et al., 2014]

Average hardness of tool steel used to make forging dies of Gas quenching and triple tempering component is 43.6 HRC, Gas quenching, cryogenic treatment (-196°C during 12 h) and triple tempering component is 43.6 HRC, Oil quenching and triple tempering component is 43.4 HRC, Oil quenching, cryogenic treatment (-196°C during 12 h) and triple tempering component is 43.1 HRC [M. Pérez et al., 2014].

Hardness of Fe75Ni25 alloy is conventional heat treated process is 174 HV. And is increased in deep cryogenic treatment process up to 336 HV, and 276 HV in Shallow cryogenic treatment process. [Y Kang et al 2011]

#### 4. CONCLUSIONS

The conclusions of this discussion are as follows:

- The Hardness of cryogenic treatment component increased as compared to conventionally heat treated component, this occurs due to the transformation of retained austenite into martensite phase.
- Deep cryogenic treatment is mostly preferred than shallow cryogenic treatment because of its lower deep freezing temperatures which showed more improved properties like, improved wear resistances, increased hardness.

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# Experimental Investigation and Analysis for Chatter of Face Milling Tool

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**Abstract:** This paper deals with the experimental investigations of chatter in high speed milling on VMC. In high speed machine tool chatter must be avoided for better machine life, improve surface finish, and increase tool life. The chatter in face milling is reduced by introducing the damper in the cutting tool system also investigation is carried out by introducing the shim attach with insert that provide damping. High speed and hard material applies pressures on the insert seat and shim. The shim acts as a shock absorber for the insert and work piece. The shim protects both insert and tool holder from damage due to high cutting forces. In the present work, the Carbide, Aluminum and Brass shim, material are used to find out their effect on reduction in vibration and improvement in surface finish. Finite Element Analysis (FEA) is done for finding the damping Ratio for different shim material using ANSYS software.

**Keywords:** Chatter, damping ratio, model analysis, ANSYS, VMC.

## 1. INTRODUCTION

In present day's in the manufacturing industries high-speed milling (HSM) plays a crucial role. Some examples include the fabrication of moulds and the aeroplane building industry. The key benefit of high-speed milling is that a large amount of material can be cut in a short time span with relatively small tools due to the high rotational speed of the tool. There is also a demand for increasing the automation in the production. This means that tools and workpieces are changed automatically and that the process is being monitored constantly by various sensors in VMC.

The machining of metals are often accompanied by a violent relative vibration between work piece and tool that is called chatter. There are three different types of mechanical vibrations present as forced vibrations, free vibrations and self-excited vibrations, these are present due to a lack of dynamic stiffness/rigidity of the machine tool

system comprising tool, tool holder, work- piece and machine tool itself.

Successful machining operations depends upon the dynamic relationship between the work piece and cutting tool. Under certain circumstances, the motion of the tool against the work piece can produce a self-exciting system, resulting in large amplitude of vibrations. This vibration or chatter adversely affects the life of the tool, the quality of the cut, and the speed at which operations may be performed. Understanding and properly controlling the interaction of tool/work piece dynamics to control chatter can yield to reduced costs and higher overall productivity.

## 2. LITERATURE REVIEW OF CHATTER IN FACE MILLING TOOL

In order to reduce chatter in face milling tool, some creditable works have provided several literature in below table (see table I).

TABLE 1: Summary of Literature Review

Main criteria	Title of literature	References
High-speedmilling, Regenerative chatter	Prediction of regenerative chatter by modelling and analysis of high-speed milling	R.P.H. Faassen et al. (2003)
Cutting Force Coefficients, HSM, Chatter	Chatter stability prediction in milling using speed-varying cutting force coefficients	N.Grossi et al.(2014)
Chatter prediction, Milling	RCPM—a new method for robust chatter prediction in milling	G. Totis et al.(2009)

Main criteria	Title of literature	References
Chatter, Milling, Spectral modeling	Theoretical–experimental modeling of milling machines for the prediction of chatter vibration	Giuseppe Catania et al.(2011)
Energyefficiency, facemilling, vibrati-on analysis	Vibration analysis and energy efficiency in interrupted face milling processes	HugoM.B.de Carvalho et al.(2015)
Milling, Vibration, Cutting forces, Titanium alloys	Vibration analysis of cutting force in titanium alloy milling	Armando ItaloSetteAntonialli et al.(2010)
Geometry, Modeling Simulation, milling	Modeling and analysis of a novel approach in machining and structuring of flat surfaces using face milling process	Mohammadjafar Hadad et al.(2016)
FFT, Half-Power Bandwidth Method, Harmonic analysis, Ansys	Experimental determination of structural damping of different materials	Himanshu Mevada et al.(2016)
Aluminum, High-speed Cutting	Design and manufacturing technology of high speed milling cutter for aluminum alloy	Hongbin Chang et al.(2017)

### 3. EXPERIMENTAL SETUP

The experiments were carried out on the CVM 640 (VMC) Milling machine with two face milling tool one is special purpose face milling tool 63 mm dia. 4 inserts cutting tool and second one is 63 mm dia. 5 inserts, work piece Plate of 75*25*300 mm of 2062 mild steel 130 BH work material were used for the experiments. The machining is done using CNMG 120412 (Carbide) insert. The experiments were

conducted at constant feed per tooth 0.15. Three different cutting speed 200m/min, 250m/min, 300m/min are taken, three different depth of cut 0.8mm, 1.0mm, 1.2mm, without shim and with three different shim material Carbide, Brass and Aluminum are taken for experiments. Surface roughness is measured with SJ 210 surface roughness tester (-200  $\mu\text{m}$  to 150 $\mu\text{m}$ ). The experimental setup is shown in Figure 1(a), 1(b), 1(c).

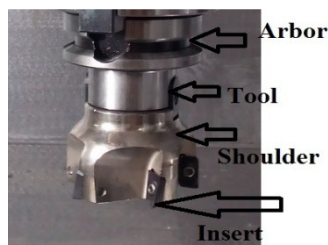


Fig 1(a) Face milling tool Without Shim

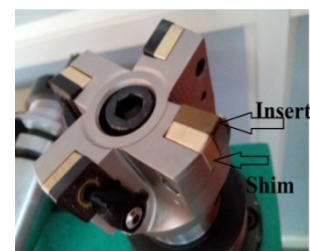


Fig 1(b) Face milling tool With shim

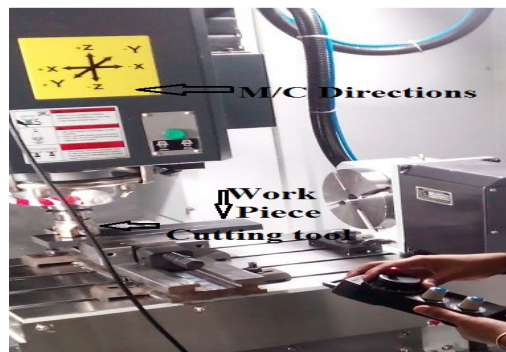


Fig 1(c) VMC for milling operation



#### 4. EXPERIMENTAL RESULTS DISCUSSION AND DYNAMIC MOTION BEHAVIOUR

- Experimental results are described in terms of surface roughness for different cutting speed, Depth of cut and Different shim.
- Experimental result as surface roughness for different cutting speed clearly shows that without shim surface

roughness value ranges from 0.78  $\mu\text{m}$  to 2.52  $\mu\text{m}$  and with the brass shim surface roughness value is from 0.84  $\mu\text{m}$  to 1.77  $\mu\text{m}$ . With different shim material Aluminum has surface roughness value from 2.0  $\mu\text{m}$  to 6.92  $\mu\text{m}$ . Carbide has surface roughness value from 2.95  $\mu\text{m}$  to 5.98  $\mu\text{m}$ .

- From this we can clearly state that the Brass is having good surface finish.

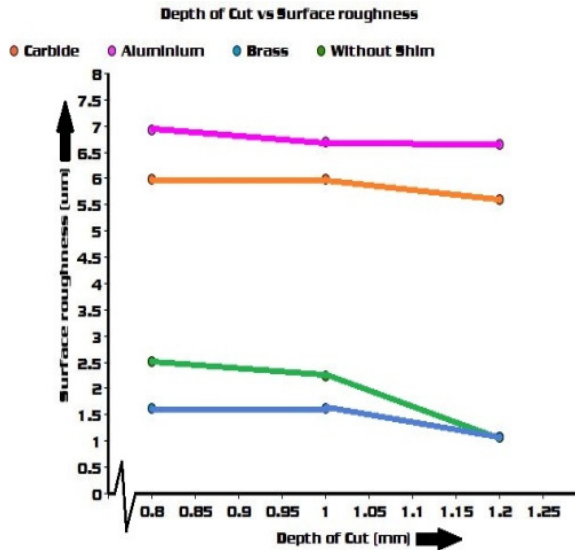


Fig 2(a) depth of cut vs surface roughness

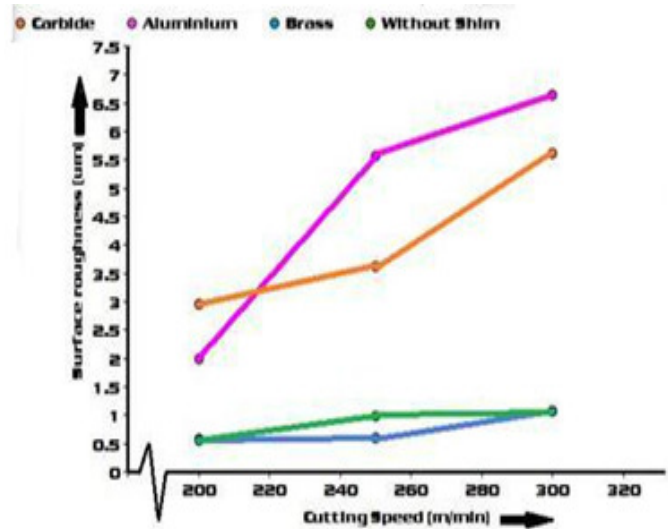


Fig 2(b) cutting speed vs surface roughness

TABLE. 2: Experimental Results Table with Shim 4 inserts and No shim with 5 inserts

No. of run	Shim material	Cutting speed	Depth of cut	Surface roughness
1	No shim	250	1.0	1.07
2	No shim	300	1.2	1.08
3	Aluminum	250	1.0	6.05
4	Aluminum	300	1.2	6.65
5	Carbide	250	1.0	4.47
6	Carbide	300	1.2	5.61
7	Brass	250	1.0	0.60
8	Brass	300	1.2	1.06

##### 4.1 Dynamic Motion Behaviour

Different combination of depth of cut, cutting speed, for without shim and with shim material as damper are used with this total 36 experiments based on DOE has been carried out and results of that is obtained in form of motion plots. This plot consists of X direction and Z direction as

cutting force direction for this both operating direction motion analysis has been done with the help of Time domain plots, plot of FFT, plot of point care and orbit plot. Output parameters as surface roughness helps to analyze the motion behavior.

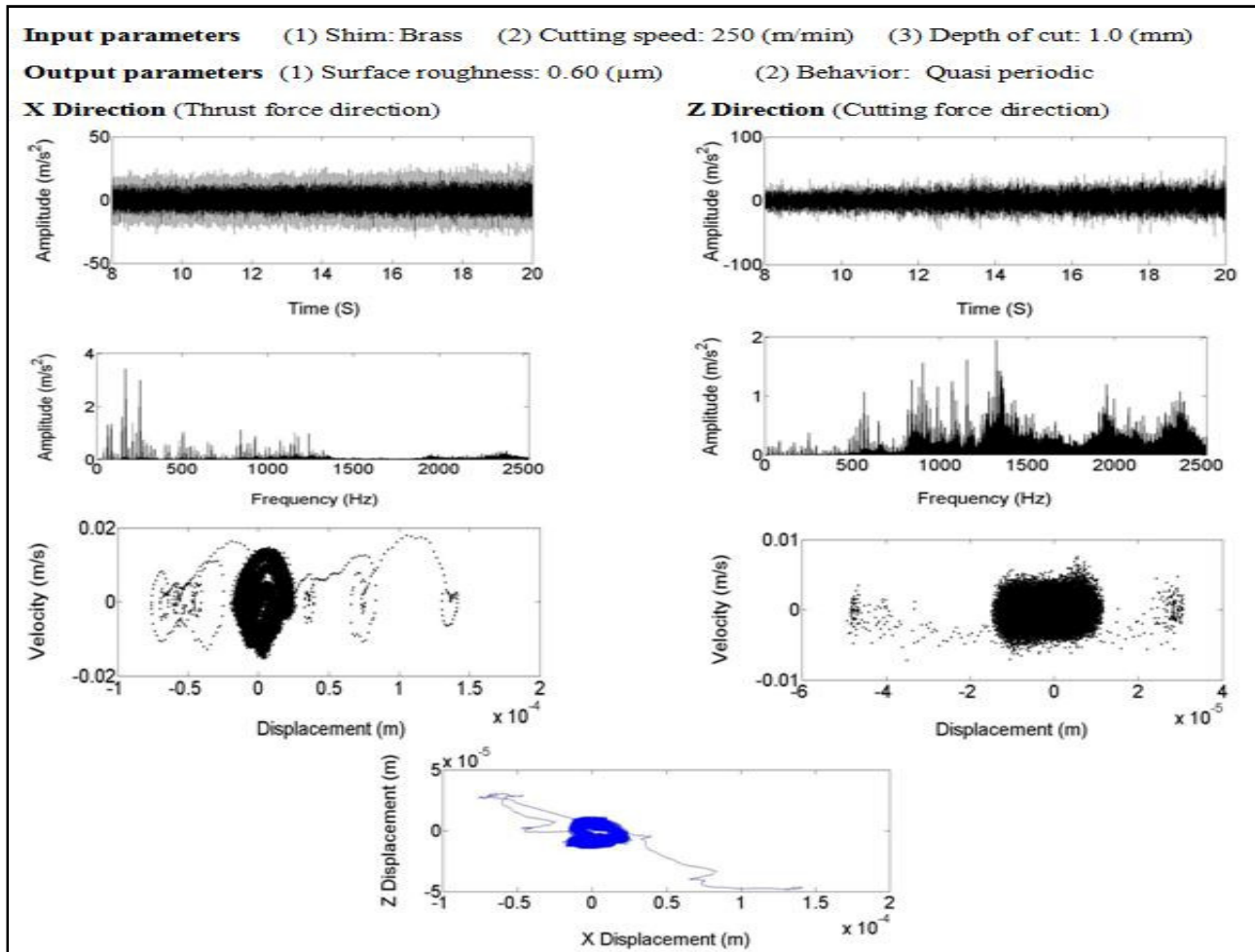


Fig. 3. Brass Shim, Cutting speed 250 m/min and Depth of cut 1.0 mm.

## 5. CONCLUSION

In the present work, a computational model is used for finding out damping ratio and validated with the Experimental study to analyze the chatter in milling operation. The observation of this study can be used to reduce the chatter and improve surface roughness 0.6  $\mu\text{m}$ , 0.8  $\mu\text{m}$  and 1.6  $\mu\text{m}$  where as compared with without shim, brass again gives good surface finish at 250 m/ min (1010 r.p.m ) at depth of cut 1.2 mm and 1.0 mm with surface roughness of 0.6  $\mu\text{m}$  and 1.0  $\mu\text{m}$ . Rather than this result without shim and brass has having same and near approximate surface roughness. Aluminum is not justified for use in operation because of having very high roughness value as 6.9  $\mu\text{m}$ . Conventionally used carbide shim gives poor surface roughness compared to Brass and without shim. From motion behavior again aluminum is not justified for use in operation because of chaotic behavior and conventionally used carbide also gives most of chaotic and multi periodic motion behavior. Motion behavior also justify the concluding results of surface finish. In this

cutting frequency and thrust frequency of brass shim having less value compared with the without shim as well as the motion behavior of brass is having quasi periodic motion (figure 3) and that shows the reduced chatter for most off combination of input parameter compared to without shim.

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# Electromagnetic Crimping: Eco-friendly Green Pulse Technology Forming

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**Abstract:** Electromagnetic forming is based on Lorentz force. The joining mechanism is creating inference fit by plastic deformation, without any chemical bonding or fasteners. The electromagnetic pulse technology (EMPT) crimping represents a technical and economic alternative to mechanical crimping processes. EMPT provides non-contact processes for joining, welding, forming and cutting of metals by application of strong, short pulsed magnetic fields without using high pressure, high temperature and poisonous gases. This joining method can replace the equivalent of 80 spot welding. The non-contact process that EMPT offers, results in safe, non-hazardous and non-polluted working conditions. Due to these advantages and reduced use of lubricants, EMPT promotes clean room condition and green forming, which is the need of an hour to reduce environment pollution. EMPT is a classical example of integrated approach of advanced eco-friendly manufacturing process, ergonomics and industrial engineering.

**Keywords:** Electromagnetic Pulse Technology, Crimping, Electromagnetic Forming, Lorentz force, EMPT

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## 1. INTRODUCTION

Ergonomics is the branch of science which deals with providing comfortable, safe, non-hazardous and non-polluted working conditions. Traditional joining processes like welding involve use of high pressure and high temperature. In addition, use of poisonous gases in conventional joining processes result in unsafe, hazardous and polluted working environment which lead to decrease in productivity. Electromagnetic pulse technology crimping technique is an excellent answer to these problems.

EMPT came up in the 1960's and was adopted by many researchers within the following decade. Basically, whenever an electrical current is rapidly imposed within an electrical conductor, it will develop a magnetic field. This change in magnetic field will induce eddy currents in any nearby conductor that generally run in a direction opposite to the primary current like in a transformer. These eddy currents develop their own magnetic field and cause a mutual repulsion between the work piece and actuator. This technique is quite general and is suitable for any workpiece made from a good conductor provided the current pulse is of a sufficiently high frequency. The spatial distribution of pressure can be controlled by the configuration of the actuator and the overall force magnitude is largely controlled by the discharge energy.

The research work covered the fundamentals of the EMPT as well as its applications. Dietz et. al. derived a scheme for calculation of the magnetic pressure acting on the work piece by use of the energy balance equation (Dietz, 1967). Later, the same authors could validate their theoretical considerations by experimental analysis. Within these, they

used Hall-sensors to gain the magnetic flux density distribution data inside a compression coils bore (Dietz, 1969). Bühler and V. Finkenstein manufactured shrink-fit connections between copper tubes and steel rods with the help of the EMPT. However, the bearable force of these connections was quite low (Bühler, 1968). After some years of apparently little scientific interest, research activities in Electromagnetic Pulse Technology (EMPT) again began being increased. However, the field of applications was quite widespread. Beneath further work in fundamentals, like materials behavior, the field of sheet metal forming by EMPT became more and more of interest.

EMPT did not found widespread application in industrial manufacturing processes till now due to low life times of the EMPT system components, especially of the coils used for generation of the magnetic pressure. But it finds its place in modern manufacturing processes due to increased demand of environment friendly world class working conditions. The present volume of this research presents the unique and innovative approach of use of EMPT for joining process.

## 2. WORKING PRINCIPLE OF EMPT

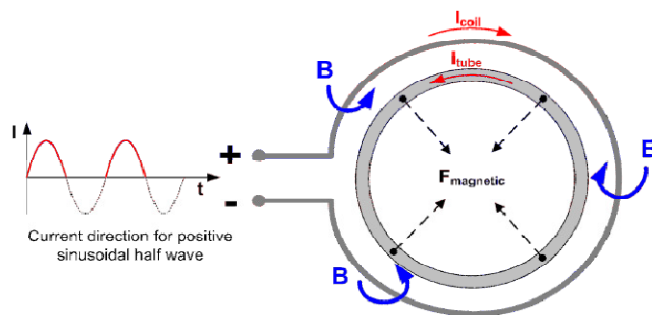
An electrical conductor experiences a force when a current is applied to it in a magnetic field. This force is called Lorentz force after its discoverer. In addition, the current generates a magnetic field itself. Thus, two parallel, current-carrying conductors repel each other, if the currents flow in different directions. If a tube is inserted into an electromagnetic coil, the coil can be seen as one conductor and the tube as the other. An eddy current is induced in the skin of the tube and flows according to Lenz's rule in the

opposite direction to the current in the coil, if an alternating current is applied to the coil as shown in figure 1. Therefore, the tube wall experiences a radial force acting inwards.

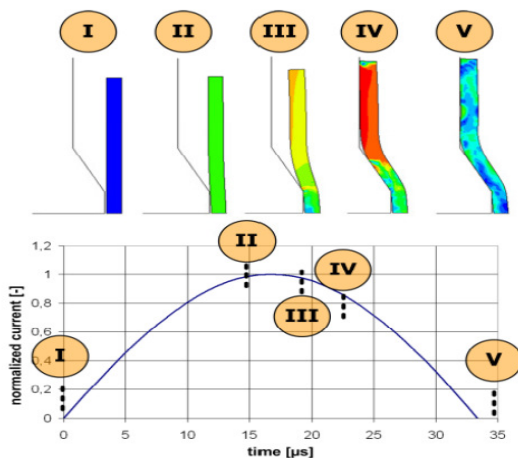
EMPT crimping represents a technical and economic alternative to mechanical crimping processes. The non-contact process that EMPT offers, creates a more uniform pressure over the circumference with none of the variation nor tool marks inherent in mechanical processes. Thus the EMPT crimp is more uniform with no radial nor longitudinal misalignment, e.g. when joining metal fittings to rubber hoses as shown in figure 2.

If the coil current changes its direction, the current induced into the tube is also changed. Thus, the coil current and the current induced into the tube remain counter rotating with the direction of the magnetic force is kept constant. The magnetic force compresses the tube radially within microseconds.

However, because of the tube's inertia, the forming process is phase delayed to the pressure build-up. Figure 3 illustrates the forming process at five moments of time.



**Fig. 1. Metallic tube inserted into an electromagnetic coil**



**Fig. 2. Finite element analysis of crimping a tube onto an insert**



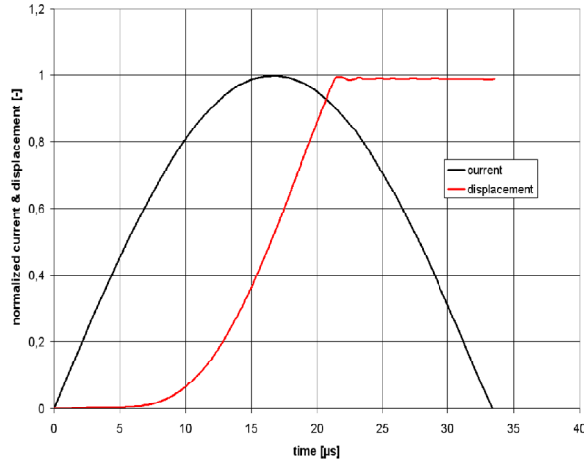
**Fig. 3. EMPT crimping of steel fittings onto rubber hoses**

During the rise of the magnetic pressure some microseconds will elapse before first material displacement of the tube is visible. Within this time, internal stresses are built up inside the tube which first must overcome the material's yield strength and the inertial stresses. Subsequently the diameter reduction of the tube takes place. As the process continues, the rate of diameter reduction is significantly increased with a final geometry reached prior to current direction change in the coil. Figure 4 illustrates the correlation between current-time history and displacement-time history for the above given tube compression example. The displacement data are related to the tube's tip point. After  $7 \mu s$  first displacement is identifiable. Only  $15 \mu s$  later, the forming operation is accomplished.

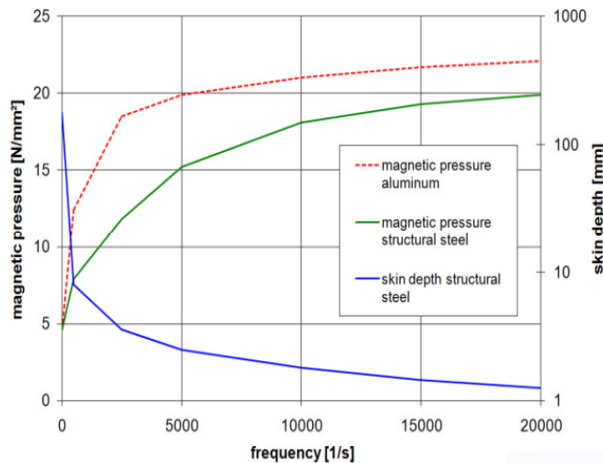
Figure 5 illustrates the correlation between discharge frequency, skin depth and magnetic pressure for an aluminum Al6060 tube of 1mm wall thickness. 80% of the current maximum. The deformation ends, when the current has only slightly exceeded its maximum. In this case, nearly the complete magnetic energy is applied to the moving workpiece. The correlation between discharge frequency and degree of efficiency is caused by 3 fundamentals:

1. The magnetic pressure is dependent on the width of the air gap between coil (or field shaper) and workpiece. When the gap distance increases to more than 1mm, significant magnetic pressure losses are identifiable. Hence, the main portion of magnetic pressure should be applied to the workpiece, before the air gap becomes bigger than 1mm.
2. Maximum magnetic pressure is build up, when the induced current builds up a magnetic field in the same magnitude as the coil's field. i.e. if a single wound coil is used, the current, induced into the workpiece should equal the coil current. For this, the skin depth should be smaller than the work piece wall thickness. Only in this case, inductive coupling losses are minimized.

3. However, there is a frequency dependent damping counteracting the beneficial effects of higher frequencies given in point 1 & 2. According to Winkler, in free tube compression, the radial displacement increases first with increasing frequency. After exceedance of an optimal frequency, the radial displacement decreases again (Winkler, 1973).



**Fig. 4. Current and correlating displacement –time history for a tube compression**



**Fig. 5. Correlation between discharge frequency, skin depth and magnetic pressure for an 1mm wall thickness structural steel tube**

### 3. EXPERIMENTAL SET UP FOR EMPT

As illustrate by Peihui Zhang, (2003) an EMPT systems consist of three major parts: (i) The pulse generator, (ii) a coil and, (iii) a field shaper. The magnetic pressures for forming of metallic materials are in the range of 100 N/mm². To generate these pressures, it is necessary to apply pulsed currents in the range from 100 kA to more than 1000

kA. The energy required has to be stored in a pulse generator, consisting of a capacitor bank, a charging unit and a high current switch. The pulse generator and the coil of the EMPT systems create a resonating oscillating circuit, i.e. the energy

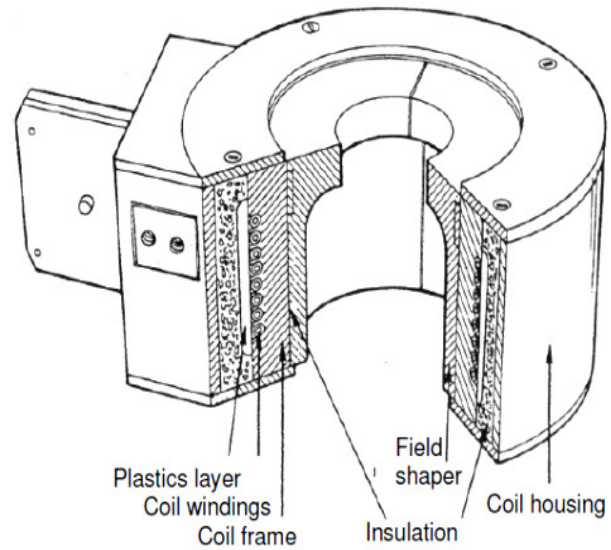
$$E = \frac{1}{2}CU^2$$

which is stored in the capacitors is transferred into the coil with a magnetic energy E and vice versa;

$$E = \frac{1}{2}LI^2$$

Where, C = Circuit's capacitance, U = Charging voltage, L = Inductivity and I = Discharging Current.

Coils and field shapers are used to focus magnetic pressure onto electrically conductive work pieces. The coil consists of one or more electrical windings and is made from a highly conductive material, usually a special copper or aluminum alloy as shown in figure 6. The coil cross-section is usually between 10 and several 100mm² depending on the required currents to transfer.



**Fig. 6. Section of a multiple winding coil**

The field shaper is sectioned with at least one radial slot, and is electrically insulated against the work piece and the coil. The coil length and the field shaper length at its outer diameter are the same, with the gap between coil and field shaper kept as small as possible.

As the electrical pulse is transferred, the coil induces an eddy current in the skin of the field shaper, which flows to the inner surface of the field shaper bore by means of the radial slot. The inner diameter of the field shaper is similar to the outer diameter of the work piece. Glenn S. Daehn



(2006) expressed that the length of the inner bore, however, is usually shorter than that of the coil and thus provides a concentration. This has two effects: firstly, the magnetic field lines are concentrated onto the ridge and, on the other hand, the non-uniform magnetic field of coils with multiple windings is homogenized.

If a field shaper is used, the magnetic pressure that has to be reacted by the coil is smaller than the pressure that acts onto the work piece, thereby significantly increasing the service life of the coil compared to a direct-acting coil, leading to higher efficiency and more favorable costs. The state of the art coils developed by PST products GmbH have been optimised using numerical methods, giving an average coil life time of 2, 000, 000 pulses Schäfer, R. and Pasquale P. (2009)

A variety of work piece diameters and geometries can be processed with a standard coil and the addition of a suitable field shaper with minimal time and effort. A field shaper can be changed within two minutes. A field shaper is not a requirement with many part-specific systems using single purpose coils in service, but can add to plant and part flexibility on the shop floor.

#### 4. WORKING PROCEDURE

The sequence of operation is:

1. The workpiece is positioned in the coil.
2. With the high-power switch initially open, the charging unit charges the capacitors.
3. With charging voltage reached in usually less than 8 seconds, the charging switch is opened and the high-power switch of the coil circuit is closed, releasing the stored energy of the capacitors, providing a sinusoidal alternating current in the providing a sinusoidal circuit of the coil and capacitors.
4. After a few oscillations, the alternating current is damped to zero with the tube shrinking to its final geometry during the first half wave of the alternating current as show in figure 7.

The EMPT systems used in industry generally have a discharging frequency in the range 6 to 30 kHz. EMPT systems developed by PST products GmbH are characterized by very high discharging currents, high discharging frequencies, short cycle times and state of the art process monitoring and control algorithms. The life time of the capacitors is more than 2 million pulses, with scheduled maintenance intervals for the high-power switches approximately every 500, 000 pulses. The discharging currents are between 100 kA and 2000 kA at a voltage of 10 kV to 16 kV, depending on the model as shown in figure 8. The application of electromagnetic crimping for steel tube and for dissimilar materials for

lightweight seat structures of cars and aircraft are shown in figure 9 and 10 respectively.

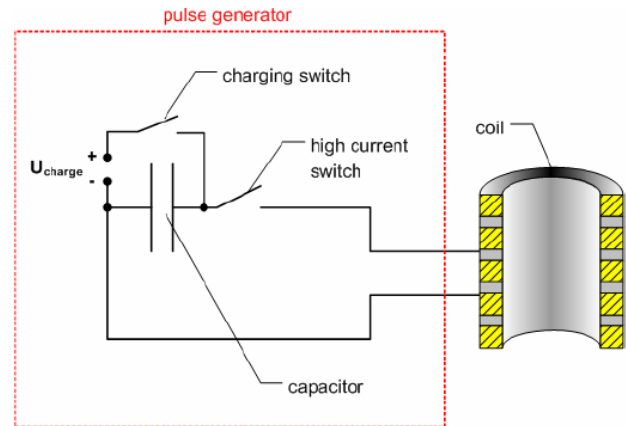


Fig. 7. Principle of the pulse generator and the coil

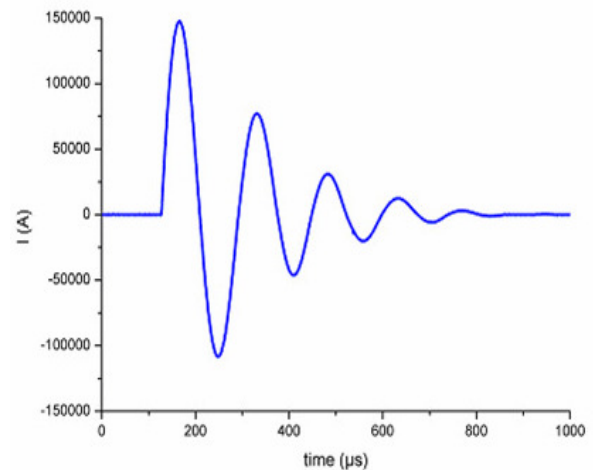


Fig. 8. Oscillation of a typical discharging current

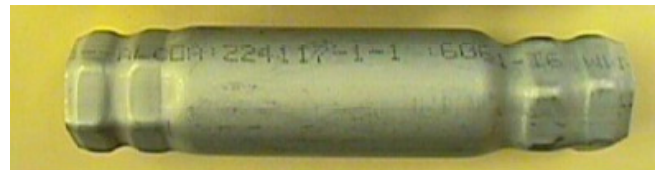


Fig. 9. Electromagnetic Crimping of a steel tube



**Fig. 10. Electromagnetic crimping of dissimilar materials for lightweight seat structures of cars and aircraft**

## 5. CONCLUSION

Electromagnetic pulse technology crimping is a classical example of integrated approach of advanced manufacturing process, ergonomics and industrial engineering. It improves formability i.e. the amount of stretch available without tearing and it suppresses wrinkling. However, there are certain limitations of this technology like non-conductive materials cannot be formed directly, but can be formed using a conductive drive plate. High voltages and currents involved require careful safety considerations. In addition, large sheet metal components cannot readily be formed, due to current limitations on the design of very large coils.

Still EMPT has several advantages in comparison to conventional joining processes. Forming can be combined with joining and assembling with dissimilar components

including glass, plastic, composites and other metals with close tolerances as spring back can be significantly reduced, which leads to increase in productivity. EMPT crimping also reduces tooling costs as single sided dies are sufficient. The foremost advantage is that mechanical contact with the workpiece is not required, this avoids surface contamination and tooling marks. As a result, a surface finish can be applied to the workpiece before forming. It is environmentally clean process as no lubricants are necessary. Compare to conventional forming process, there is no noise in crimping process, which creates better working environment and promotes world class eco friendly working conditions.

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# Development of Activated TIG Welding Technology for Duplex Stainless Steel 2205 for Achieving Sustainability

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**Abstract:** Activated Tungsten Inert gas (A-TIG) welding technology is a novel variant of the TIG welding process wherein the penetration capability of the process is enhanced and thus making the process sustainable. In the current study, four different types of fluxes  $\text{SiO}_2$ ,  $\text{ZnO}$ ,  $\text{TiO}_2$  and  $\text{NiO}$  were used for the A-TIG welding process for making bead on plate trials on 6 mm thick plates. Weld surface was observed for extent of spatter and macrostructures were developed for observing the weld bead dimensions. Different aspects of Bead dimensions such as weld depth of penetration, bead width depth to width ratio were measured and analyzed. The results exhibited the full and secure penetration (greater than plate thickness) with  $\text{TiO}_2$  flux. Based on results obtained insights into depth enhancing mechanisms were proposed and role of more than one mechanism was observed with certain fluxes.

**Keywords:** A-TIG, Welding, DSS, sustainability.

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## 1. INTRODUCTION

Duplex ferritic/austenitic stainless steels are widely used in industries such as chemistry, food, pharmacy, marine etc. due to their high performance characteristics (Badji et al., 2004). Duplex Stainless Steels possess higher strength than austenitic stainless steels, higher toughness than ferritic stainless steels and high resistance to stress corrosion cracking (Chen & Yang, 2002; Jiang, Chen, Huang, & Liu, 2003; Park & Lee, 2001). These desirable properties are due to its two-phase microstructure consisting of approximately equal amounts of austenite and ferrite (Badji et al., 2008; Taban, 2008). These steels possess moderate weldability to almost all conventional welding processes.

Out of all conventional arc welding processes Tungsten Inert Gas (TIG) welding process is one of the most sought process where high quality welds are required (Modenesi, Apolinario, & Pereira, 2000; Naik & Reddy). However, major limitations such as low productivity and relatively shallow penetration particularly in single pass autogenous operation limits the use of this process (Kumar & Sathiya, 2015; Leconte, Paillard, Chapelle, Henrion, & Saindrenan, 2007). A partial answer to this restriction can be provided by applying a thin layer of chemical powder (termed as activating flux) on the surface of the plate before welding and thereby enhancing the weld penetration depth (Dhandha & Badheka, 2015; Vora & Badheka, 2015, 2016a). This technology is termed as Activated TIG (A-TIG) welding process. A-TIG welding has been experimented by researchers in the domain on different steels. An in depth studies was carried out of authors Vora and Badheka (Vora & Badheka, 2015, 2016a, 2016b, 2017) wherein they successfully developed A-TIG technology for the

ferritic/martensitic steels. Their studies on investigation of mechanism and weld morphology proved the fact that the technology can enhance the weld depth penetration drastically. Furthermore authors Naik and Reddy (Naik & Reddy) reported the enhancement in penetration with the A-TIG welding of Duplex stainless steel. Out of several mechanisms proposed for deeper penetration, reversed Marangoni and arc constriction are the major phenomenon held responsible for this enhancement in penetration.

A-TIG welding enables faster welding of the plates by increasing the weld depth of penetration in single pass as compared to other conventional TIG welding process (Naik & Reddy; Ramkumar, Kumar, et al., 2015). Reduction in number of passes, gas consumption, power efficiency and many other features confirms the sustainability of the process. There are limited studies reported in open literature for the A-TIG welding of DSS steels. Thus the aim of current study is to analyze the effect of 4 different single component oxide based fluxes on the weld penetration and mechanisms for the A-TIG welding process.

## 2. METHODOLOGY

The base material Duplex Stainless Steel (2205) used in the present study was procured having chemical composition as shown in Table 1. Four different fluxes such as  $\text{SiO}_2$ ,  $\text{ZnO}$ ,  $\text{TiO}_2$  and  $\text{NiO}$  used in the study were procured in packed and powdered form. The flux available in powdered form is not possible to apply evenly on the weld surface. Thus, the powder is converted to paste form by mixing it with acetone as shown in Fig.1. Acetone has a tendency to vaporize quickly leaving the evenly distributed oxide flux on the surface. Base material plate of 6 mm thick was cut into

strips of 100 × 25 (mm) for bead on plate trials and flux paste was applied on 10 mm width at the center of strip throughout the length as shown in Fig. 1 with a paint brush. Flux thickness was taken approximately as 0.15 mm. In order to ensure this, the quantity of flux was calculated as shown in Table 2 and entire amount of flux was applied over the desired area. For having a uniform amount of flux

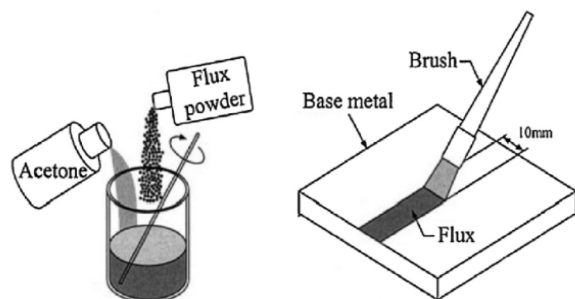
constituents over entire length of strip, the brush was moved in both forward and reverse direction over the desired area until entire flux paste was consumed. In order to measure the peak welding temperatures, a contact type “K” type thermocouple was fixed at the center of the plate by drilling a hole of approx. 2 mm diameter and 3 mm depth during the welding trials.

**TABLE 1: Chemical composition of base material DSS 2205**

Element	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	%N	%W
wt. %	0.02	0.299	1.657	0.023	0.005	22.946	5.441	3.068	0.158	0.03

**TABLE 2: Flux weight and Peak welding temperature**

Flux	Density (g/cm ³ )	Weight of Flux (gm)	Peak Temperature (°C)	Voltage (V)
No Flux	-	-	656	13.5
SiO ₂	2.65	0.397	723	13.5
ZnO	5.61	0.841	763	13
TiO ₂	4.23	0.634	1050	13.5
NiO	6.67	1.001	1010	13.5



**Fig. 1. Preparation and application of flux paste.**

Extensive welding trials were conducted using the welding parameters as welding current 160 A and travel speed 120 mm/min. The arc was moved along the centre line of the welds and all the welding parameters were controlled, however arc voltage which is not normally a control parameter was measured. In order to compare the effect of oxide fluxes, samples were welded with same operating conditions by applying four oxide fluxes individually as well as TIG welding without flux.

After welding, samples were taken from the centre of the welded plate and subjected to mechanical grinding, polishing followed by etching using Adler’s Reagent to produce a bright surface. A Digital Camera/Stereo Microscope was used to observe all the samples.

### 3. RESULTS AND DISCUSSION

#### 3.1 Effect of Oxide Fluxes on Weld Surface

The weld surfaces of plates prepared using TIG and A-TIG welding process using different fluxes are as shown in Table 3. It can be observed that a spatter free surface was attained using TIG welding whereas varied amount of spatter was obtained at the periphery of the A-TIG welded bead (Vora & Badheka, 2015). The extent of spatter found on the front surface followed the descending order using fluxes NiO > SiO₂ > TiO₂ > ZnO. This was attributed to the slag layer formed due to the flux layer applied before welding.

As observed on the back side, full & secure penetration (> than plate thickness) was obtained for A-TIG welded sample using fluxes NiO and TiO₂. On the other hand, with the use of fluxes ZnO and SiO₂ there are no sign of any full depth penetration. Notably TiO₂ gives full length secure more than plate thickness penetration. While NiO flux is not able to give throughout length penetration. The reason for the same may be absence of stable and thorough depth enhancing mechanism along the length.

#### 3.2 Effect on Weld Bead Dimensions

The weld bead dimensions are as shown in Fig. 2. It can be seen from the table that flux TiO₂ gave penetration of 6.82 in a 6 mm plate. While though NiO imparted full depth penetration but the penetration profile was not continuous through the length. An important consideration which can be observed was that, fluxes ZnO, SiO₂ tends to increase the penetration as compared to normal TIG welding, however full and secure penetration was not obtained. Furthermore, it can also be observed that the Depth to

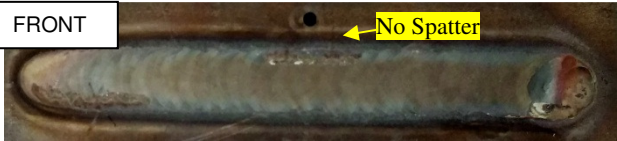
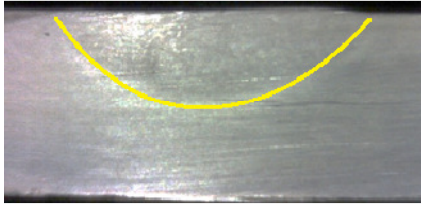
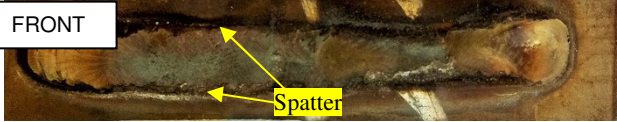
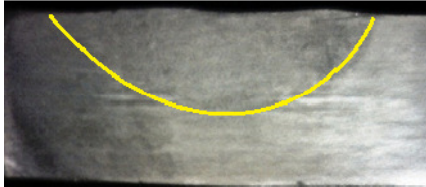
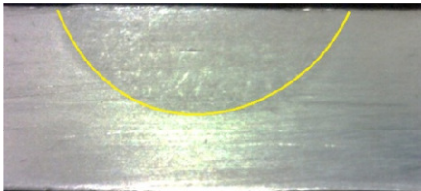
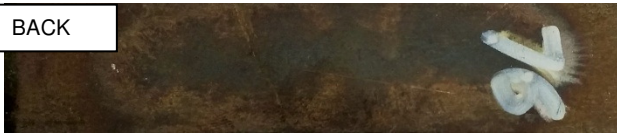
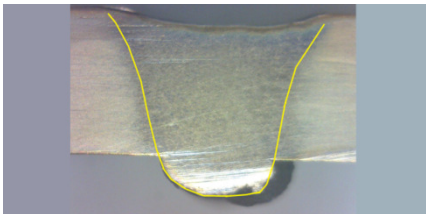
Width (D/W) ratios for all the fluxes are found to be higher compared to TIG welding without flux (Fig. 3). This, indicates, the presence of reverse Marangoni flow which is one of the main activation mechanism. In reversed Marangoni flow the direction of fluid flow (molten metal in present case) during welding is radially inwards giving a deeper and narrower bead (Dhandha & Badheka, 2015; Nayee & Badheka, 2014; Ramkumar, Bajpai, et al., 2015; Vora & Badheka, 2015). However, The drastic penetration increase in case of NiO and TiO₂ hinted towards the existence of another depth enhancing mechanism which responsible for deeper penetration.

### 3.3 Effect on Peak Welding Temperatures

Table 2 also shows the Peak temperature values attained

during TIG and A-TIG welding. It can be observed that the peak temperatures achieved with the use of fluxes TiO₂ and NiO are much higher compared to TIG welding. This may be due to the presence of arc constriction mechanism (Berthier, Paillard, Carin, Pellerin, & Valensi, 2012; Shyu, Huang, Tseng, & Chou, 2008; Tathgir, Bhattacharya, & Bera, 2015; Vora & Badheka, 2015, 2016b). Arc constriction mechanism tends to focus the arc energy towards the centre by constricting the arc shape. The total arc energy which was same in all cases (all fluxes) was concentrated at the centre which increased the peak temperatures even though the welding conditions and parameters were same. Relatively similar peak temperature values with fluxes SiO₂ and ZnO indicated a complete absence of this phenomenon. This may be the reason for limited penetration increase with these two fluxes.

**TABLE 3: Surface appearance of welded plates and Macrostructure**

	Surface Appearance Of Welded Plates		Macrostructure
TIG Welding	FRONT		
	BACK		
A-TIG Welding with SiO ₂ Flux	FRONT		
	BACK		
A-TIG Welding with ZnO Flux	FRONT		
	BACK		
A-TIG Welding with TiO ₂ Flux	FRONT		

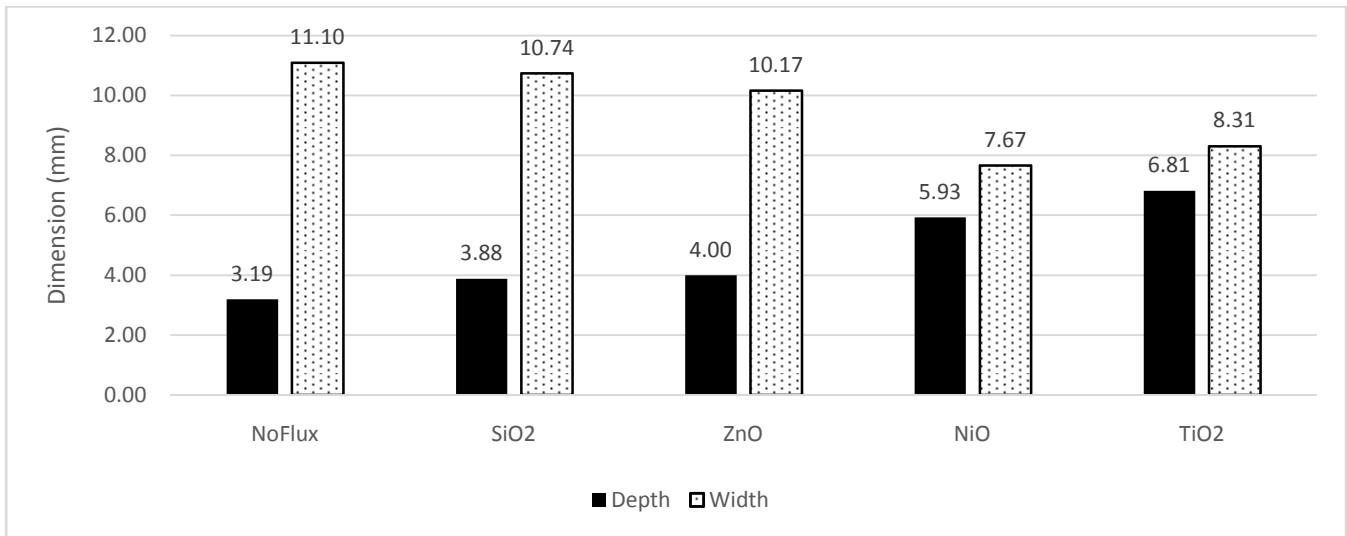
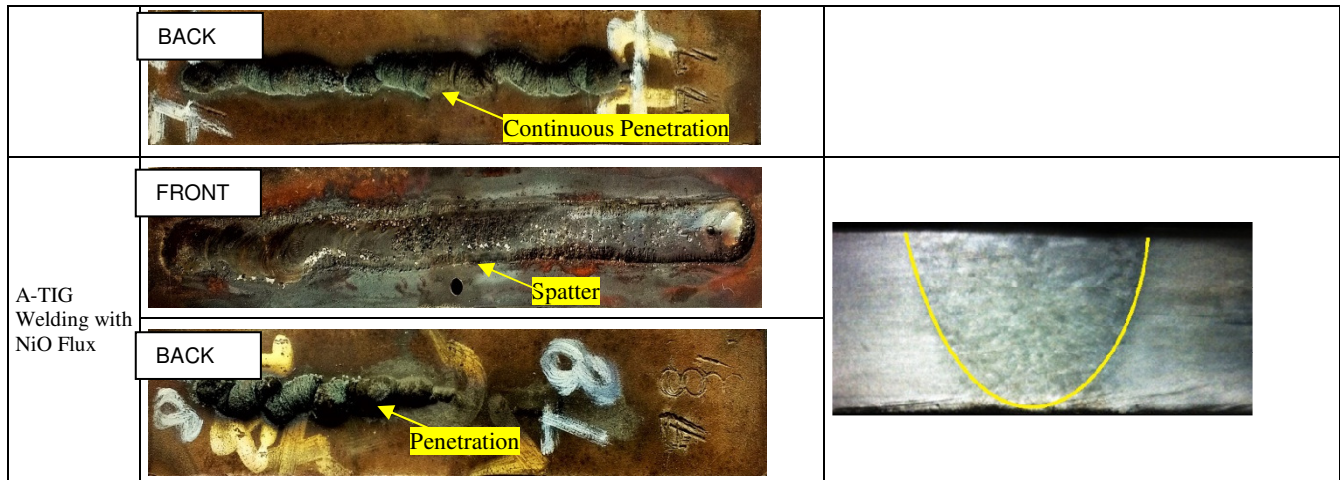


Fig. 2. Weld Bead Dimensions

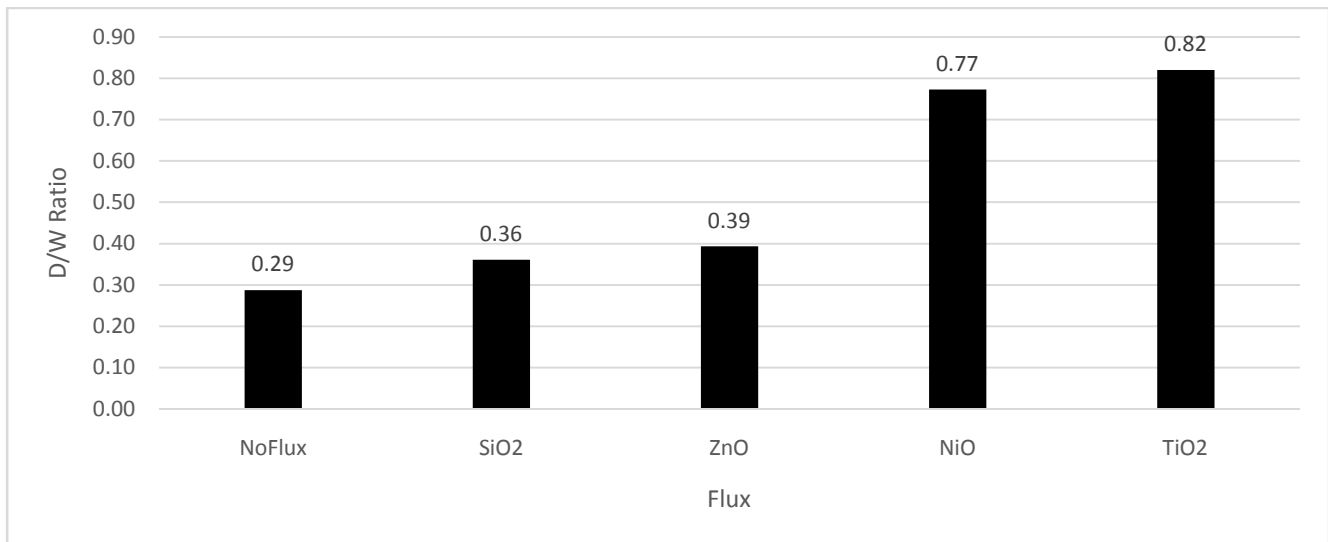


Fig. 3. D/W ratio for different fluxes

#### 4. CONCLUSION

Based on the study conducted, following important conclusions can be proposed.

- Full and secure penetration was obtained with the use of fluxes  $\text{TiO}_2$  and  $\text{NiO}$  however with the flux  $\text{NiO}$  penetration profile was not continuous through the length
- Fluxes Study shows the presence of reverse Marangoni flow which is one of the main activation mechanism for increased penetration compared to conventional TIG Increase in the D/W ratio with the use of oxide fluxes proved the presence of reversed Marangoni effect during A-TIG welding.
- Higher peak welding temperatures during the A-TIG welding with fluxes  $\text{TiO}_2$  and  $\text{NiO}$  indicated the presence of arc constriction mechanism which was completely absent with other fluxes.

Selected process parameters along with the suggested fluxes can be further tried for full size butt welding of 6 mm thick DSS steel plates.

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# Design and Structural Analysis of Missile Nozzle

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**Abstract:** Nozzle is the component of a missile, rocket or air breathing engine that produces thrust. Converting the pressure of the hot chamber gases into kinetic energy and directing that energy along the nozzle axis. The nozzle considered for analysis in this project work is designed for short range missile and is made of maraging steel 250 alloy. In this work stress analysis of this nozzle under the different static test pressures are considered. Nozzle is modeled in SOLIDWORKS and analysis is carried out in ANSYS 14.0. Finite Element Analysis is carried out to find the stresses, thermal flux and displacement in nozzle components. Finally, from the results it is concluded that the structure is safe and has adequate margin of safety in components of nozzle assembly.

**Keywords:** SOLIDWORKS, ANSYS, Nozzle, Missile.

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## 1. INTRODUCTION

Nozzle is the component of a missile, rocket or air-breathing engine that produces thrust. Converting the pressure energy of the hot chamber gases into kinetic energy and directing that energy along the nozzle axis.

The propellant is composed of a fuel, typically liquid hydrogen (H₂), and an oxidizer, typically liquid oxygen (O₂). The propellant is pumped into a combustion chamber at some rate ( $\dot{m}$ ) where the fuel and oxidizer are mixed and burned. The exhaust gases from this process are pushed into the throat region of the nozzle. Since the throat is of less cross-sectional area than the rest of the engine, the gases are compressed to a high pressure. The nozzle itself gradually increases in cross-sectional area allowing the gases to expand. As the gases do so, they push against the walls of the nozzle creating thrust. Mathematically, the ultimate purpose of the nozzle is to expand the gases as efficiently as possible so as to maximize the exit velocity ( $V_{exit}$ ). This process will maximize the thrust ( $F$ ) produce by the system since the two are directly related by the equation

Where  $F$ =Thrust force

$\dot{M}$ =Mass flow rate,

$V$ =Exit exhaust gas velocity at nozzle exit,

$p$ = Exit pressure of the exhaust gases at the nozzle exit

$P$  = Ambient pressure of the atmosphere

$A$ = Exit cross-sectional area of the nozzle exit.

## 2. EXPANSION AREA RATIO

In theory, the only important parameter in missile nozzle design is the expansion area ratio ( $e$ ), or the ratio of exit area ( $A_{exit}$ ) to throat area ( $A_{Throat}$ ). Fixing all other variables (primarily the chamber pressure), there exists only one such ratio that optimizes overall system performance for a given altitude (or ambient pressure). However, a

missile typically does not travel at only one altitude. Thus, an engineer must be aware of the trajectory over which a missile is to travel so that an expansion ratio that maximizes performance over a range of ambient pressure can be selected. Nevertheless, other factors must also be considered that tend to alter the design from this expansion ratio-based optimum. Some of the issues designers must deal with area nozzle weight, length, manufacturability, cooling (heat transfer), and aerodynamic characteristics.

## 3. MATERIAL

The nozzle is critical component of the missile. Material used to manufacture nozzle should possess high strength, high temperature resistant, good machinability. The nozzle components are made of 18 Ni maraging steel 250 (ASTM A579 Code 72). This material used in annealed condition to acquire high strength, good machinability and resist the high temperature.

## 4. DESIGN CONSIDERATION

Nozzle consists of three parts they are:

**Nozzle End Dish:** - Nozzle end dish is fixed to combustion chamber. So the left end of the nozzle end dish is constrained i.e., translation and rotational movements are arrested ( $u_x=u_y=u_z=0$ ).

**Nozzle Neck:** - Nozzle neck is fixed to nozzle end dish. Hot gases from hot chamber flows to nozzle neck through the end dish. The diameter of nozzle decreases from end dish to neck.

**Nozzle Cone:** - Nozzle cone left end is fixed to the nozzle neck and the other end is free. From nozzle cone high pressure gases extruded to outside by this pressure only missile can move with high velocity.



## 5. PROBLEM SPECIFICATION

Nozzle is attached to combustion chamber and it exerts high pressures and temperature. It consists of three components end dish, neck and cone. The end dish is subjected to both radial pressure and thrust. Neck and cone subjected to radial pressure. The components are analysed for strength considering material properties at elevated temperature. Also temperature fluxes are calculated for the nozzle.

## 6. TYPES OF NOZZLES

**Conical nozzle:** Most military jet air craft employ the simple conical nozzle with adjustable conical angle as their propulsive device. In this conical nozzle external supersonic expansion occurs.

**Bell shaped nozzle:** In this nozzles exhaust gases are forced into a converging throat region of low area before expand in bell shaped nozzle. In this nozzle expansion occurs internally.

**Convergent-divergent nozzle:** This nozzle has convergent section followed by a divergent section so called as convergent divergent nozzle. From inlet heat gases to the throat (minimum area) and then decelerates. As pressure is lowered the flow eventually chokes.

## 7. DEVELOPMENTS IN MISSILE NOZZLE

Through the concept of the nozzle has been around for many years, little actual flight or test experience has been available until recently.

### 7.1. Early Development

The first serious studies of nozzles were performed in Germany in conjunction with the development of the turbojet engine. Engines like those used on the Messer Schmitt me 262, utilized a plug center body to vary the throat area for better performance. Jeffry J. Berton scientist of NASA said that the United States air force. And missile dyne together spent over \$500 million on the development of engines during the 1950s, 1960s, and 1970s.

The development effort conducted by the NASA Lewis Research Center (now known as NASA Glenn) in Cleveland, oh, and by Missile dyne's Nevada test Facility, tested aero spike engines ranging in size from subscale cold-flow models to a full-scale 250, 000lb thrust engine. These tests included 73 ground tests of full-sized engines totaling over 4000 seconds of operation. Similar work was underway in West Germany from 1965 to the early 1970s in support of a heavy lift launch vehicle called Neptune. The propulsion arrangement for this concept consisted of a "toroidal plug nozzle" that behaved much like an aero spike with primary and secondary flows.

## 8. NOZZLE MATERIAL AND ITS PROPERTIES

High Temperature Materials and Their Requirement Recent developments in nuclear power, jet aircrafts, ballistic missiles and rocketry have increased the demand for materials that have good corrosion resistance, strength characteristics and particularly, creep resistance at high temperatures. High temperature use of materials can give rise to several problems such as:

1. Accelerated oxidation and/or corrosion.
2. Creep.
3. Grain boundary other weakening.
4. Allotropic and other phase changes.
5. Modification of conventional properties.

Therefore, the material for high temperature use must be such that it can withstand these difficulties and perform its functions satisfactory during service. The nozzle components are made of 18 Ni maraging steel 250 (ASTM A579 Code 72). This material used in annealed condition to acquire high strength, good machinability and resist the high temperature. The composition used for this material is given in table.

## 9. COMPOSITIONS

TABLE 1: Chemical composition of maraging alloy 250

Chemical Elements	Min	Max
Nickel	17.0	19.0
Molybdenum	4.6	5.1
Cobalt	7.0	8.5
Carbon	-	0.03
Aluminum	0.05	0.15
Phosphorus	-	0.01
Sulfur	-	0.01
Silicon	-	0.10
Titanium	0.3	0.5
Manganese	-	0.01
Iron	68.0	-

In order to withstand high pressure and temperatures, its strength is acquired by the composition of these materials like Carbon, Nickel, Sulphur, Manganese, Titanium, Silicon and Molybdenum etc.

### 9.1. Nickel

It increases the strength and toughness of the steel. Nickel contributes great strength and hardness with high elastic limit, good ductility and good resistance to corrosion. An alloy containing 25% of nickel possesses maximum toughness and offers greater resistance to rusting, to rust in corrosion and burning high temperature. It has zero coefficient of expansion.



### 9.2. Manganese

It improves the strength of the steel in both the hot rolled and heat treated condition.

### 9.3. Silicon

It behaves like Nickel it has high elastic limit as compared to ordinary carbon steel.

### 9.4. Cobalt

It gives red hardness by retention of hard carbides at high temperatures it tends to the decarburize steel during heat-treatment. It increases hardness and strength and also residual magnetism and coercive magnetic force in steel for magnets.

### 9.5. Molybdenum

It posses extra tensile strength and is used for air-plane fuselage and automobile parts. It can replace in high speed steel.

## 10. GENERAL CHARACTERISTICS

This composition has following characteristics

1. Good machinability.
2. Good surface finish.
3. High strength.
4. Excellent corrosive resistance.

## 11. MODELLING OF NOZZLE

### 11.1 Analysis of Nozzle

Analysis of the Nozzle is carried over in the following steps:

**Building the Model:** Where the geometry of nozzle is specified and model is created in SOLIDWORKS.

**Applying the Load:** This is carried out in ANSYS14.0. Meshed model is imported to ansys and pressures are applied.

Viewing the Results: This is also carried out in ansys. In this we can view stresses and deformations.

**GEOMETRIC MODELLING:** Modelling has been carried over in SOLIDWORKS software is very easy modelling critical components. SOLIDWORKS is very user friendly and parametric.

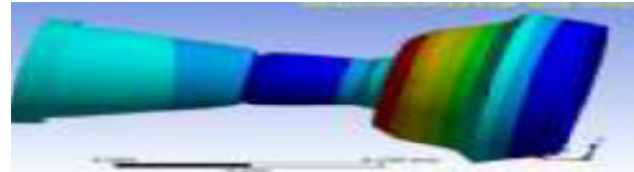
## 12. PRESSURE LOADS

COMPONENTS	PRESSURE LOADS
NOZZLE END	10
NOZZLE NECK	5
CONE	2

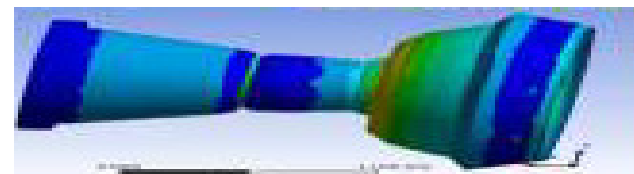
Pressure loads are used for structural analysis.

**ALL LOAD ARE IN MPA**

## 13. RESULTS



**RESULTANT DISPLACEMENT**



**STRESS**

### 12.1 Resultant displacement and stress according to load

DISPLACEMENT:-4.17e5

STRESS:-181.05

REMARKS:-safe

## 14. CONCLUSION

The Nozzle is analyzed for different inertia load cases in addition to test pressure. A global final element analysis (FEA) (static analysis only) is carried out to arrive at the stresses and deformations in critical components. Finally from the results obtained, it is concluded that all the stresses induced are well within the allowable limits and the structure is safe.

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# Process Parameters Optimization of Friction Stir Welded Butt Joint: A Review

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**Abstract:** Friction stir welding plays vital role in industrial revolution for joining similar and dissimilar metals. This review paper mainly concentrates on various advanced optimization techniques used by previous researchers for finding out the optimum values of process parameters with their effects. In this paper, various methodologies and optimization aspects are thoroughly overviewed and critical observations are noted down. The graphical representation shows the most influencing process parameters and best-suited optimization technique is suggested which may become ready information for the forthcoming researchers to establish their line of action. This review paper is also helpful for finding out the effect of various process parameters such as tool rotational speed, welding speed, tool pin profile, tool pin diameter, tool shoulder diameter, the ratio of tool shoulder diameter to tool pin diameter, tool tilt angle, tool plunge depth, axial force, etc.

**Keywords:** Friction stir welding, Optimization, Tool rotational speed, Welding speed, Axial force, Tensile strength

## 1. INTRODUCTION

The researchers working in aerospace, marine, automotive and rail industries are more concerned for the reduction in energy consumption by using several lighter alloys. Aluminum, copper, magnesium and nickel based alloys can be extensively used due to their exclusive properties such as low density, high strength to weight ratio, high formability, good corrosion resistance, etc. Joining of these alloys by using conventional fusion welding processes is a tedious job and results in various welding defects such as porosity, distortion, solidification cracking, etc.

The exclusive feature of FSW is its ability to join metals below their melting temperature, hence reduces welding defects which occurs due to uneven heat distribution. FSW finds large application in aluminum based industries, however recently it is also used for joining copper, titanium, magnesium, nickel based alloys and plastics. FSW is becoming more popular as it can join similar as well as dissimilar metals for making weld joints from 1 mm thickness to 80 mm thickness. FSW is used for fabricating various welding joints such as butt weld, spot weld, lap weld, T-joint, continuous drive friction welding for joining two cylindrical rods, tube to tube plate weld joint, etc.

## 2. REVIEW OF PROCESS PARAMETERS OPTIMIZATION OF FSW FOR BUTT JOINT

Friction stir welding for obtaining butt weld joint (Fig.1) uses non-consumable tool which rotates at high-speed and when comes in contact with the metal to be joined, it produces heat due to friction which in turn allows the material to be softened. Due to the rotation of tool, this

softened material is forced to flow from front to the back of the tool pin where it cools and solidifies, which produces weld joint. Since the welding takes place below melting temperature, it significantly reduces distortion and other welding defects. The FSW process involves various process parameters such as tool rotational speed (TRS), welding speed (WS), tool pin profile (TPP), tool pin diameter (TPD), tool shoulder diameter (TSD), ratio of tool shoulder diameter to tool pin diameter (D/d), axial force (AF), tool pin length (TPL), tool geometry (TG), tool tilt angle (TTA), tool pin rotational speed (TPRS) assisted shoulder rotational speed (ASRS), plate thickness (PT), etc. The output responses considered are tensile strength (TS), yield strength (YS), hardness (H), elongation (E), ultimate tensile strength (UTS), etc.

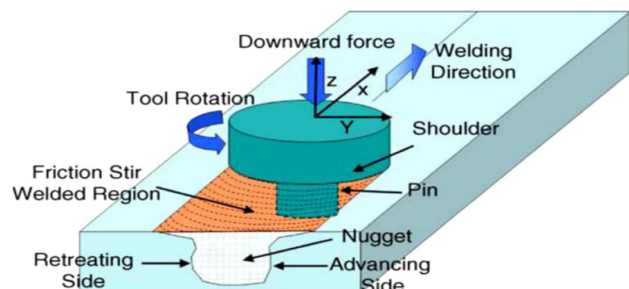


Fig. 1. Schematics of the friction stir process for butt joint (Mishra and Ma, 2005)

From the literature review, it is observed that most of the research work is carried out on FSW butt joint configuration since its wide application in industries. In this article, an attempt has been made to overview most of the

**Table I :** Summary of FSW process parameters optimization review

Author (s), Year	Input variable (s)	Objective(s)	Material	Machine	Tool specification(s)	Optimization technique (s)	Conclusion	Critical observation(s)
Jayaraman et al., 2009	TRS, WS and AF	TS	A319 (175 mm X 75 mm X 6 mm)	FSW machine	High carbon steel tool	Taguchi method	TRS is found to be most influencing parameter	All parameters are having significant effect on TS
Tansel et al., 2010	TRS and WS	TS, YS, E, H of weld metal, H of HAZ	AL plates (Al 1080) (5×50×150 mm)	FSW machine	High speed steel tool of 20mm diameter and 4mm plunge depth	GONNS	GONNS is found to be suitable for optimization of process parameters	The ANN-GA combination is recommended for other optimization problems
Biton et al., 2010	TRS and WS	UTS and YS	3.2 mm thick rolled sheet of AA 2198 T3	Five axes DMG CNC machine	Cr-Mo steel tool of TSD = 24 mm, TPD = 4 mm, PD = 3mm and TTA = 2°	The desirability function algorithm	UTS is dependent on rotational speed of tool and YS is strongly dependent on welding	The weld joints performed in cold condition have good mechanical properties
Aydin et al., 2010	TRS, WS and TSD	TS and E	AA1050-H22 (360 mm × 200 mm × 4 mm)	Vertical milling machine	High speed steel tool (HSS)	Grey relation analysis and Taguchi approach	Rotating speed of tool has highest contribution of 65.61 % on output response.	Grey based Taguchi method can be effectively used for solving multi-objective optimization
Koilraj et al., 2012	TRS, WS, TG and D/d	TS	AA2219 and AA5083 (150mm × 65mm × 6mm)	FSW machine	H13 grade tool steel	Taguchi method	Butt joint Efficiency found to be 90%. The D/d ratio is the most influencing parameter	Better mechanical properties are obtained if stronger metal is placed on advancing side
Dinaharan and Murugan, 2012	TRS, WS and AF	UTS	AA6061/ZrB2 plates (100 mm × 50 mm × 6 mm)	FSW machine	high carbon high chromium steel tool	Generalized reduced gradient method	The increase in TRS, WS and AF to a certain limit increases UTS and then decreases.	Generalized reduced gradient method is attempted by very less researchers
Bozkurt, 2012	TRS, WS and TTA	UTS	HDPE sheets (50mm X 130mm X 4mm)	FSW adapted milling machine	SAE 1050 Steel tool 40 HRC having TPD = 6mm and shoulder diameter = 18mm	Taguchi method	The most important factor is TRS having 73.85 % contribution	It is observed that HDPE sheets can be successfully welded by FSW
Vijayan, Raju and Rao, 2012	TRS, WS and AF	TS	AA5083 (300mm × 150mm × 5mm)	FSW machine	M2 steel tool with TSD = 15mm and TPD = 5mm	Grey relation analysis and Taguchi approach	The rotational speed of the tool is found to be the most significant factor	It was observed that the input power increases significantly with increase in the axial force

Table I : (Continued..)

Author(s), Year	Input variable (s)	Objective(s)	Material	Machine	Tool specification (s)	Optimization technique(s)	Conclusion	Critical observation(s)
Babajanzade et al., 2013	AF, TRS, WS, and TG	YS, H and TS	AA7075 (200 mm x 100 mm x 6mm)	CNC milling machine	High speed steel tool	ANFIS	ANFIS System has good competency for optimizing process parameters	Less number of researchers used ANFIS system for optimization
Periyasamy et al., 2013	TRS, WS and AF	UTS, notch TS and weld nugget hardness	AA6061 (150 mm x 100 mm x 6 mm)	FSW machine	high speed steel tool	RSM	The TRS is found to be most influencing parameter followed by WS and AF	TRS is mainly responsible for increasing the temperature at weld joint
Al-Jarrah et al., 2013	WS, TSD, TRS and PT	YS and H	Aluminum alloy having 4.2 % Mg and 0.42 wt % Si	Milling machine	High carbon steel tool	RSM	The results obtained were matched with welding appearance quality and experimental results	Optimum range of input variables can be obtained by conducting more number of trail experiments
Bilgin, Meran and Canyon, 2014	TRS, WS, AF and TTA	TS	AISI 430 (3 mm x 100 mm x 200 mm)	Vertical milling machine	A cemented carbide equilateral triangle tip tool	Genetic algorithm	The optimum values are TRS = 1120 rpm, WS = 125 mm/min, CTF = 4.5 KN and TTA = 0°	Quality of joint is quite poor having lower TRS with higher WS and having higher TRS with lower WS
Shojaeefard, Akbari and Asad, 2014	TRS and WS	Peak temperature, HAZ width	AA5083 Alloy 6mm thickness	CNC milling machine	High speed steel tool	A Thermo-mechanically coupled, 3D FEM	Welding force decreases with increase in TRS and decrease in WS. This may lead to increase in tool life	The training algorithm of back-Propagation is sufficient for Predicting peak temperature, HAZ zone width and welding
Ahmadi, Arab and Ghasemi, 2014	WS, TRS and TTA	Tensile shear strength	Polypropylene sheets with 20 % carbon Fiber	CNC milling machine	HSS tool with TSD = 12mm, TPD = 4mm	Taguchi method	The percentage contribution of process parameters found as follows WWS = 79.06 %, TRS = 12.29 % and TTA = 5.41 %	FSW can be successfully implemented to polypropylene composites and it was attempted by very few
Elanchezhia et al., 2014	TRS, WS and AF	Impact strength and TS	AA6061 and AA8011(160 mm x 50mm)	CNC milling machine	HSS tool	Taguchi method	ANOVA results show that the contribution of TRS is higher i.e. 35.79 % for impact strength and contribution of AF is higher i.e. 64 % for TS	In this paper impact tests were conducted on charpy machine according to specifications of ASTM-E23.
Loffi and Nourouzi, 2014	TRS, WS and TSD	TS and micro hardness	AA7075-T6 (3x 150 mm x 100 mm)	FSW machine	H13 hot work tool steel	RSM	With increase in TRS and WS the TS and micro hardness increases and then decreases steadily	Preheating system gives improved mechanical properties and defect free joint

Table I : (Continued..)

Author(s), Year	Input variable(s)	Objective (s)	Material	Machine	Tool specification(s)	Optimization techniques	Conclusion	Critical observation(s)
Dhancholia, Sharma and Vyas, 2014	TRS and WS	TS, YS, H and impact strength	AA6061 and AA7039	CNC milling machine	HSS tool of TSD= 16mm and probe length = 4.7mm	RSM	TRS and WS found as most influencing parameters	Multiple response problems can be easily solved using desirability method
Kumar and Kumar, 2014	TRS, TTA and TG	TS and % E	AA6061 and AA6082 ( 100 mm x 35mm x 7.5mm)	CNC milling machine	HSS tool TSD = 16 mm and TPD = 6mm	Taguchi based grey relation analysis	The TRS found to be the most influencing process parameter having 96.24 % of contribution	It was observed that the overall cost of experimentation was minimized because it provides optimum solution with minimum trials
Rambabu et al., 2015	TRS, WS, TPP and AF	Corrosion resistance	AA2219-T87 ( 240 mm x 160 mm x 7 mm)	FSW machine	HSS tool	SA algorithm	The most influencing process parameter is found to be TG and hexagonal tool pin profile	A computer program using MATLAB for the algorithm was developed to optimize the process variables
Li, 2015	WS, TRS, ASRS	TS	AA2219 (300 mm x 80mm x 5mm )	FSW machine	HSS tool	RSM	Improvement of 5.2 % maximum TS of reverse dual rotation FSW was observed	The direction of tool pin and assisted shoulder are reversed which increases TS of FSW joint
Sahu and Pal, 2015	WS, TRS, TSD and TPL	UTS, YS % E, H, compress ive	AM20 Mg alloy ( 100 x 100 x 4 mm )	FSW machine	H13 tool steel TSD= 16-24 mm, TPD= 6 mm and PD 3.5 mm	Taguchi Grey relational analysis	The most influencing parameter is shoulder diameter for Case I and welding speed for case II	Grey relational analysis with Taguchi technique shows better mechanical properties for multi- objective optimization of
Vijayan and Rao, 2016	TRS, WS, AF and TPP	UTS and tensile E	AA 6061 & AA 2024 (300mm x 150 mm x 6.25mm )	CNC vertical milling machine	H13 Hot work steel tool	ANFIS	The ANFIS model using "gbelimf" is accurate and can be used to improve TS	It shows that ANFIS models are capable of generating better predictions of tensile properties compared to RSM
Alkayem, Parida and Pal, 2016	TRS, WS, TG, D/d and TPL	UTS, YS, % E, bending angle and H	Al alloy (wt %) Cu- 0.05, Si-0.2, Fe-0.1, Al-balance and 200mm x 100mm x 6mm size	CNC milling machine	Stainless steel (SS-310)	GA, differential evolution (DE), PSO	The real GA, DE and PSO are able to find weld characteristics which are better than binary GA	From the aforesaid case study, it is observed that PSO is more suitable for optimization of FSW Process
Liu et al., 2017	TPRS and ASRS	Temperat ure variation	Aluminum 5A06 alloy	FSW machine	HSS tool	Finite element analysis	It was concluded that the successful welding can be achieved	The thickness of plates to be welded was considered as 80mm which is very large

previous research work which uses various advanced optimization techniques for the process parameter optimization of FSW for butt joint configuration. It was observed that, Taguchi method and Response surface methodology is mostly used to get optimum values of process parameters. Experimental welding Investigations were carried out considering different Input variables and their effects on output responses. In some cases various advanced optimization techniques were used such as Simulated annealing (SA), Particle swarm optimization (PSO), Response surface methodology (RSM), Genetically optimized neural network system (GONNS), Adoptive neuro-fuzzy interference system (ANFIS), etc. Table 1 shows summary of reviewed research papers for optimization of FSW process parameters.

### 3. CRITICAL OBSERVATIONS FROM LITERATURE REVIEW

From the literature review, the graph is plotted (Fig. 2) showing the frequency of process parameters used by the previous researchers. It is observed that the most influencing process parameters are tool rotational speed, welding speed and axial force.

- ii) The effects of process parameters observed from literature review are
  - a) The TS of weld joint increases with increase in TRS up to certain value and decreases if TRS further increases.
  - b) TRS is directly proportional to heat generated.
  - c) There is increase in TS with increase in WS up to certain limit and further increase in WS decreases TS.
  - d) WS is inversely proportional to heat generated.
  - e) AF is directly proportional to heat generated.
  - f) The % E increases with increase in TRS and AF but decreases with increase in WS.
- iii) Most of the work has been done on similar alloys and less on dissimilar alloys.
- iv) CNC vertical milling machine can be used for experimentation work.
- v) Specially designed high speed steel tool with different TPP is used for FSW.
- vi) Most of the researchers uses Taguchi method and RSM for optimization of FSW process parameters.

### 4. CONCLUSION

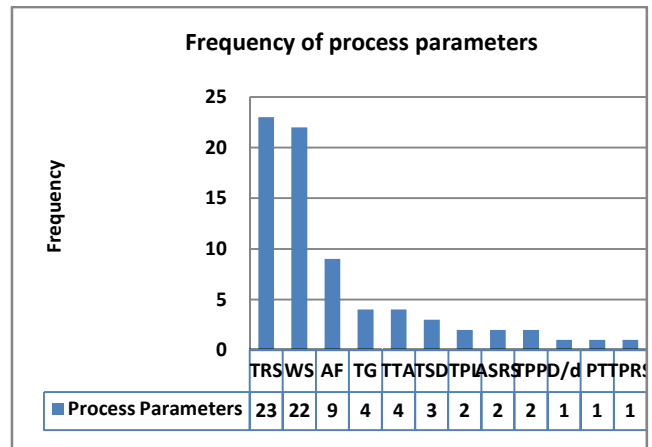


Fig. 2. Graphical representation of influence of process parameters

The presented review focuses on the extensive efforts taken by previous researchers in the field of friction stir welding for optimization of process parameters. The effects of most influencing process parameters are discussed. It identifies future scope of friction stir welding in the field of aerospace and aircraft industries, marine, rail industries, etc. It is observed that friction stir welding has wide scope for joining similar and dissimilar materials.

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# Fracture Behavior Analysis of a Finite Isotropic Plate with a Central Crack Under Various In-Plane Loading Using XFEM

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**Abstract:** This manuscript presents the fracture behaviour of an isotropic plate with a central crack having different angles subjected to various in plane loadings, such as tensile and shear loadings, through the mixed mode stress intensity factors (MMSIF). In this work, the crack is modelled using extended finite element method (XFEM) under plane strain condition using MATLAB. For the reliable and safe design of the structure, the prediction of the fracture behaviour of the crack configuration in a plate under different loading conditions through the MMSIFs becomes important. The study explains the critical level of the different crack configurations under different loading conditions.

**Keywords:** XFEM, MMSIF, plate with a central crack, in-plane loading.

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## 1. INTRODUCTION

Under fatigue loading, the fracture of a structure may occur due to cracks initiation and their propagation from discontinuities such as flaws, edges, holes or pores, etc. The fracture behaviour analysis of such structure is necessary for avoiding unexpected failure. The types of loading, material properties, geometry of the structure, crack configuration, crack length, etc. play an important role in rate of crack propagation. In the presence of loadings, cracks configuration and their lengths influence the stress distribution and stresses around the crack tip very rapidly. The intensity of these stresses is responsible to propagate the cracks and hence, it is necessary to evaluate stress intensity factors against crack growth under external loadings for predicting and analysing the fracture behaviour of the structure. The life of a structure can be predicted through the knowledge of the criticality of the crack. Moreover, the fracture mechanics enhance the reliability and reduces the weight and the cost of the structure.

## 2. LITERATURE REVIEW OF THE ENABLERS OF KM ADOPTION IN SC

There are numbers of methods for calculating the critical SIFs of the cracked structure. In this direction, the SIFs have been evaluated using a complex mapping method (Bowie, 1954), boundary collocation method (Newman, 1971), boundary element method (Yan, 2006), FEM (Jabur, 2015 and Hajdu, 2014), mesh free methods (Nguyen, 2008), XFEM (Sharma, 2014 and Mohammadi, 2008) and the extended iso-geometric analysis (XIGA) (Bhardwaj et al. 2015). These methods have been used for evaluating the SIFs of plate with different crack configuration under

different loading conditions. The FEM is widely used for the failure analysis of the structure but it has some demerits using for evaluating fracture analysis of a structure with discontinuities such as cracks. The FEM requires original discretized mesh for the conformation with a discontinuity, i.e., crack in a plate.

Further, there is a requirement of fine meshing at the crack tip which is cumbersome and time consuming. Also, when the crack grows it requires further remeshing and there is an error in the results evaluated before crack growth and after crack growth for an element and the error maximizes at global level (Gustafsson et al. 2014). Such drawbacks are overcome by using XFEM. The XFEM is Galerkin method where the approximation space is enriched with additional functions. In this direction, many researchers have worked and the first, Belytschko and Black (1999) present a minimal remeshing FEM for crack growth. Also, M  es et al. (1999) present an improvement of a new technique for modelling cracks in the finite element framework using a standard displacement-based approximation enriched near cracks.

In this paper, the fracture behaviour of an isotropic finite plate with central crack under different crack configuration and loading conditions such as tensile and shear loadings is evaluated in terms of MMSIFs,  $K_I$  and  $K_{II}$ . The predicted results of the plate under different loading conditions are also compared. Section 1 is Introduction and the section 2 explains the brief review of the literature. The section 3 presents the XFEM methodology. Results and Discussion are described in Section 4. Further, the section 5 contains conclusions.



### 3. XFEM METHODOLOGY

For the modelling of the cracks, the XFEM displacement vector function for cracks by Mões et al. (1999):

$$u^h(x) = \sum_{i=1}^n N_i(x) [\bar{u}_i + \underbrace{H(x)a_i}_{\text{for crack face}} + \underbrace{\sum_{\alpha=1}^4 [\phi_\alpha(x) - \phi_\alpha(x_i)] b_i^\alpha}_{\text{for crack tip enrichment}}] \quad (i)$$

where,  $n$  is the sets of all nodes in the mesh,  $N_i(x)$  are conventional finite element nodal shape functions,  $\bar{u}_i$  is the displacements of the nodes associated with the continuous part of the solution and  $H(x)$  is Heaviside function.  $\beta_\alpha(x)$  is near-tip asymptotic functions for representing the singularity near the crack tip.

$$\beta_\alpha(x) = \left[ \sqrt{r} \sin\left(\frac{\theta}{2}\right), \sqrt{r} \cos\left(\frac{\theta}{2}\right), \sqrt{r} \sin(\theta) \cos\left(\frac{\theta}{2}\right), \sqrt{r} \sin(\theta) \sin\left(\frac{\theta}{2}\right) \right] \quad (ii)$$

where  $(r, \theta)$  are polar coordinates in the local crack tip coordinate system.

The displacement discontinuities in the interior part of the crack are modeled by an extrinsic function based on Heaviside function  $H(x)$ . It is defined as:

$$H(x) = \begin{cases} 1 & \text{if } \phi(x) \geq 0 \\ -1 & \text{otherwise} \end{cases} \quad (iii)$$

where,  $\text{sign}(\cdot)$  is signed distance function. The Heaviside function  $H(x)$  has the value  $+1$  above the crack and  $-1$  below the crack.

#### Evaluation of MMSIFs

The relationship between SIF and J-integral is:

$$J = \frac{K_I^2}{E^*} + \frac{K_{II}^2}{E^*}$$

where,  $E^* = \begin{cases} E & \text{for plane stress} \\ \frac{E}{1-\nu^2} & \text{for plane strain} \end{cases} \quad (iv)$

$$\text{Now, the J-integral: } J = \int_{\Gamma} \left( W \delta_{1j} - \sigma_{ij} \frac{\partial u_i}{\partial x_1} \right) n_j d\Gamma \quad (v)$$

where,  $W$ ,  $\delta_{1j}$ ,  $\Gamma$ ,  $\sigma_{ij}$  and  $u_i$  are the strain energy density, Dirac delta, area inside the contour, stress tensor and displacement field vector. Now, the cracked body has two states, present state and auxiliary state. Therefore, the J-integral can be written as:

$$J^{(1+2)} = J^{(1)} + J^{(2)} + M^{(1,2)}$$

$$\text{where } M^{(1,2)} = \int_{\Gamma} \left( W^{(1,2)} \delta_{1,j} - \sigma_{ij}^{(1)} \frac{\partial u_i^{(2)}}{\partial x_1} - \sigma_{ij}^{(2)} \frac{\partial u_i^{(1)}}{\partial x_1} \right) n_j d\Gamma \quad (vi)$$

where,  $J^{(1)}$ ,  $J^{(2)}$  and  $M^{(1,2)}$  are J-integrals for present and auxiliary states and interaction integral. Now by equation (6), we have:

$$J^{(1+2)} = J^{(1)} + J^{(2)} + \frac{2}{E^*} (K_I^{(1)} K_I^{(2)} + K_{II}^{(1)} K_{II}^{(2)})$$

$$\text{and } M^{(1,2)} = \frac{2}{E^*} (K_I^{(1)} K_I^{(2)} + K_{II}^{(1)} K_{II}^{(2)}) \quad (vii)$$

The stress intensity factors for the XFEM state  $K_I^{(1)}$  and  $K_{II}^{(1)}$  are evaluated by putting  $K_I^{(2)} = 1$  and  $0$  and  $K_{II}^{(2)} = 0$  and  $1$ , alternatively in the equation (vii), we have:

$$K_I^{(1)} = M^{(1, \text{Mode I})} E^* / 2$$

$$\text{and } K_{II}^{(1)} = M^{(1, \text{Mode II})} E^* / 2 \quad (viii)$$

where,  $M^{(1, \text{Mode I})}$  and  $M^{(1, \text{Mode II})}$  are interaction integrals.

### 4. RESULTS AND DISCUSSION

In this paper, the numerical examples are presented through XFEM with a computational program in MATLAB environment to evaluate the fracture analysis of MMSIFs  $K_I$  and  $K_{II}$  of an isotropic finite plate with a central crack subjected to different loading conditions. The results are validated with the available literature work and the new results are also presented.

#### 4.1 Validation

An isotropic finite plate subjected to tensile loading is first analysed. The material parameters are Young's modulus,  $E = 3 \times 10^7 \text{ Pa}$  and Poisson's ratio  $\nu = 0.3$ . The plane strain conditions are assumed for the problem. The dimensions of the plate are  $2 \text{ mm} \times 4 \text{ mm}$  with the normalized crack lengths of  $a/W = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8$  and  $0.9$ , and a tensile stress of  $\sigma = 1.0 \text{ Pa}$  is applied to the top edge. The displacements along the y-axis are fixed at the bottom edge and the plate is clamped at the bottom left corner. The geometry, loading and boundary conditions are shown in Figure 1(a). The evaluated results are in good agreement with the results available in the literature as shown in Table I.

**TABLE I: The normalized Mode-I SIFs ( $K_I/\sigma\sqrt{\pi a}$ ) at different normalized crack lengths of an isotropic finite central cracked plate subjected to tensile loading**

$a/W$		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Normalized SIFs	Yan (2006)	1.0039	1.0269	1.0629	1.1170	1.1964	1.3150	1.5004	1.8281	2.5836
	Present Results	0.9984	1.0140	1.0538	1.0985	1.1812	1.2856	1.4756	1.7675	2.5106

### A plate with a central crack under tensile loading

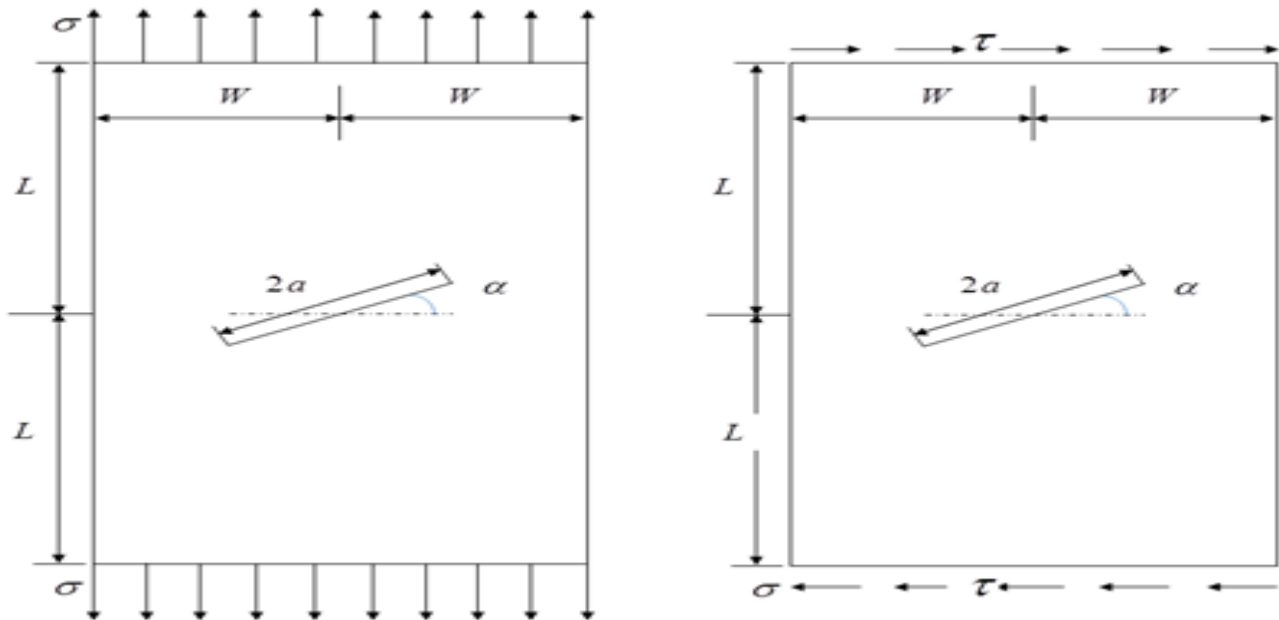
In the examples, the XFEM approach is applied on an isotropic finite plate with a central crack under tensile ( $\sigma = 1$ ) loadings for evaluating MMSIFs,  $K_I$  and  $K_{II}$  w.r.t. different crack angles. The dimensions, material properties, crack angles, boundary conditions, etc. are same as mentioned earlier. The crack angles  $\alpha$  are  $0^\circ, 5^\circ, 10^\circ, 15^\circ, 20^\circ, 25^\circ, 30^\circ, 35^\circ, 40^\circ, 45^\circ, 50^\circ, 55^\circ, 60^\circ, 65^\circ, 70^\circ, 75^\circ, 80^\circ, 85^\circ$  and  $90^\circ$ . The line diagrams of the plate under tensile loading conditions are shown in the Fig. 1(a).

The Fig. 2 shows the fracture behaviour of a finite plate with a central crack under tensile loading in terms of MMSIFs,  $K_I$  and  $K_{II}$  w.r.t. different crack angles.

From Figure 2(a), for normalized crack length  $a/W = 0.1$  to 0.9, The Mode-I SIFs,  $K_I$ , are increased as crack lengths are increased but the gap between the all the curves are continuously decreased as the crack angle is increased from

$\alpha = 0^\circ$  to  $90^\circ$ . Also the Mode-I SIFs are decreased to zero (nearly). Therefore, the Mode-I SIFs of plate with a central under tensile loading is much critical when the crack angle is  $\alpha = 0^\circ$  for all the normalized crack lengths.

From Figure 2(b), for normalized crack length  $a/W = 0.1$  to 0.9, The Mode-II SIFs,  $K_{II}$ , are the lowest (zero) at  $\alpha = 0^\circ$  and  $90^\circ$  for all the normalized crack lengths and are the highest for the longest crack lengths. As the crack angle is increased from  $\alpha = 0^\circ$  to  $45^\circ$  and  $\alpha = 45^\circ$  to  $90^\circ$  the Mode-II SIFs are increased and decreased and decreased, respectively, for all the normalized crack lengths. Also the gap between the curves are increased and decreased from  $\alpha = 0^\circ$  to  $45^\circ$  and  $\alpha = 45^\circ$  to  $90^\circ$ , respectively. Therefore, the Mode-II SIFs of plate with a central under tensile loading is much critical at  $\alpha = 45^\circ$  for all the normalized crack lengths. For the crack propagation, the Mode-II SIFs play an important role for the safe and reliable design with integrity of the structure.



**Fig. 1. The line diagrams of a finite plate with a central crack under (a) tensile, (b) shear**

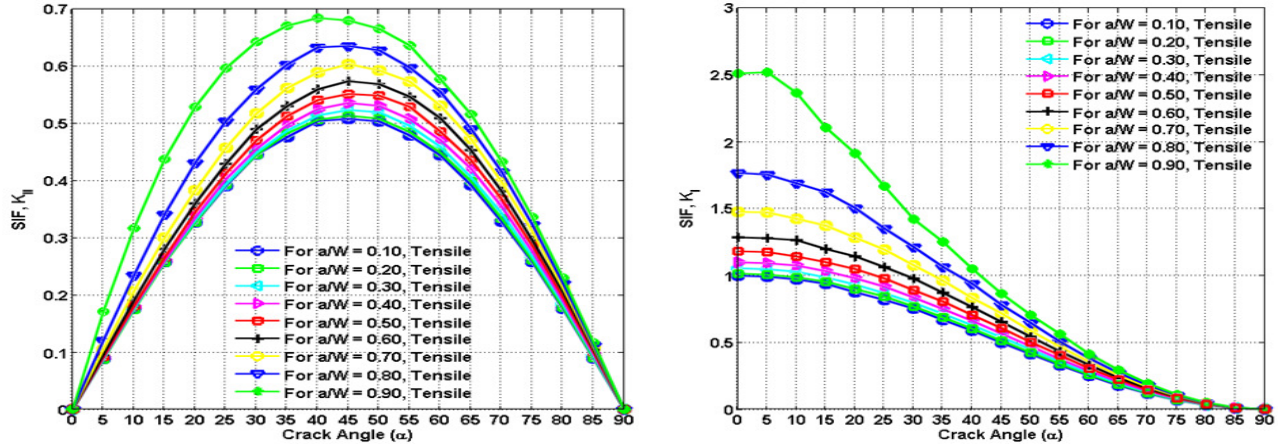


Fig. 2. Fracture behavior of a finite plate with a central crack under tensile loading in terms of MMSIFs, (a)  $K_I$  and (b)  $K_{II}$  w.r.t. different crack angles

#### 4.3 A plate with a central crack under shear loading

In the examples, the XFEM approach is applied on an isotropic finite plate with a central crack under shear ( $\tau = 1$ ) loadings for evaluating MMSIFs,  $K_I$  and  $K_{II}$  w.r.t. different crack angles. The dimensions, material properties, crack angles, boundary conditions, crack angles, etc. are same as mentioned earlier. The line diagrams of the plate under shear loading conditions are shown in the Fig. 1(b).

The Fig. 3 shows the fracture behaviour of a finite plate with a central crack under shear loading in terms of MMSIFs,  $K_I$  and  $K_{II}$  w.r.t. different crack angles.

From Figure 3(a), for normalized crack lengths  $a/W = 0.1$  to 0.2, 0.3 to 0.5, 0.6, 0.7, 0.8 and 0.9 The Mode-I SIFs,  $K_I$ , are increased from  $\alpha = 0^\circ$  to  $40^\circ$ ,  $0^\circ$  to  $35^\circ$ ,  $30^\circ$ ,  $25^\circ$ ,  $20^\circ$  and  $10^\circ$  as crack lengths are increased and are decreased

till  $\alpha = 90^\circ$  but the gap between the all the curves are continuously decreased as the crack angle is increased from  $\alpha = 0^\circ$  to  $90^\circ$ . Also the Mode-I SIFs are decreased to zero (nearly) at  $\alpha = 90^\circ$ . Therefore, the Mode-I SIFs of plate with a central under tensile loading is much critical at different crack angles for different normalized crack length but the crack angles between  $\alpha = 10^\circ$  to  $40^\circ$  are much critical for the shortest to the longest crack lengths.

From Figure 3(b), for normalized crack length  $a/W = 0.1$  to 0.2, 0.3 to 0.4, 0.5 to 0.8 and 0.9, the Mode-II SIFs,  $K_{II}$ , are increased from  $\alpha = 0^\circ$  to  $5^\circ$ ,  $0^\circ$  to  $10^\circ$ ,  $0^\circ$  to  $0^\circ$  to  $15^\circ$  and  $0^\circ$  to  $10^\circ$  and are decreased till  $\alpha = 45^\circ$  and  $\alpha = 50^\circ$  for  $a/W = 0.1$  to 0.4 and 0.5 to 0.9, respectively. Now, the Mode-II SIFs,  $K_{II}$ , are continuously increased from  $\alpha = 45^\circ$  to  $90^\circ$  for all the crack lengths. The Mode-II SIFs,  $K_{II}$ , are the least critical at  $\alpha = 45^\circ$  for all the crack lengths.

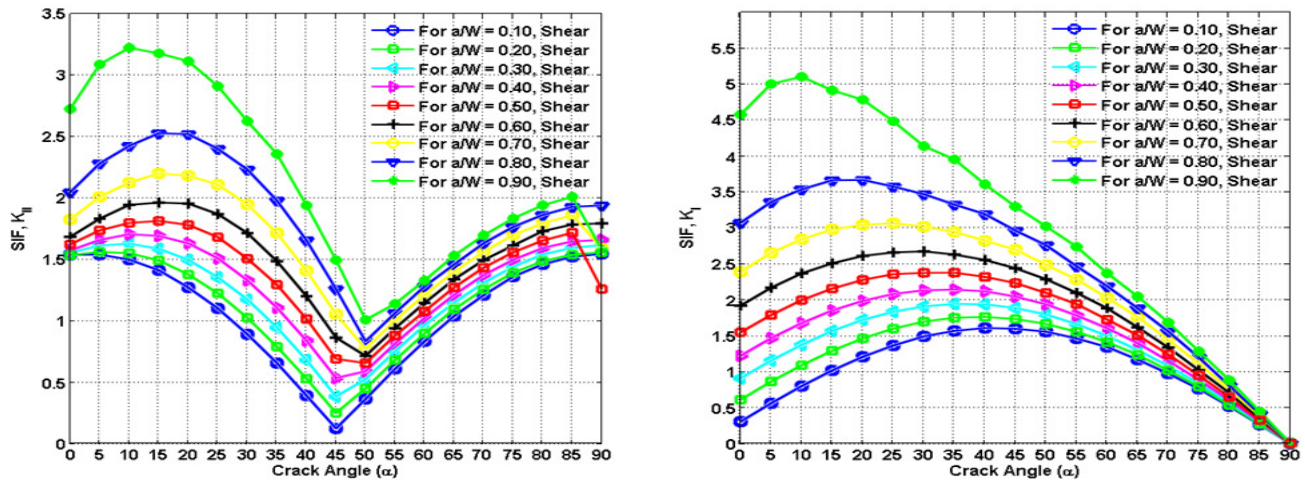


Fig. 3. Fracture behavior of a finite plate with a central crack under shear loading in terms of MMSIFs, (a)  $K_I$  and (b)  $K_{II}$  w.r.t. different crack angles

## 5. CONCLUSION

The fracture behaviour of an isotropic finite plate with different crack lengths and crack configuration under tensile and shear loadings is analysed using XFEM in terms of normalized MMSIFs and the following prediction regarding the fracture behaviour of the plate are mentioned:

Fracture behaviour of the plate with central crack under shear loading are much critical as compared to that of plate under tensile loading.

Under tensile loading, The MMSIFs are nullified when the line of the action of the crack is in the direction of the applied loading. The Mode-I SIFs dominant when the line of the action of the crack is perpendicular to the applied loading. The Mode-II SIFs come in picture only when the line of the action of the crack is in between the transverse and parallel to the applied loading.

Under shear loading, the MMSIFs dominant at nearby area of the line of the action of the crack and it is perpendicular to the applied loading for the longest crack. The Mode-I SIFs are nullified when the line of the action of the crack is in the direction of the applied loading and the Mode-I SIFs are the highest for the shortest crack when the line of the action of the crack is at  $\alpha = 45^\circ$ . The Mode-II SIFs are much critical when the line of the action of the crack is parallel to the applied loading. For the normalized crack lengths, The MMSIFs are the most critical when the plate are under shear loading. The Mode-II SIFs are much critical nearly at  $\alpha = 45^\circ$  for the shorter cracks when the plate is under the tensile loading in comparison.

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# Recent Applications of Scanning Electron Microscope and its Variants in Industries: A Review

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**Abstract:** Advanced materials are applicable to various service conditions in addition to different environmental backgrounds. To avoid chances of failure, it is always recommended to understand the behavior and crystalline information of these materials. Hence this review work can be helpful for many researchers and industries for finding out appropriate approach. Advanced developments in material characterization with the help of literature review of scanning electron microscope (SEM) and its different approaches are discussed in this paper. Main focus is kept on the SEM used for surface topography, morphology, chemical composition, corrosion behavior, fracture tendency and crystallographic information of the materials. Over the last two decades electron backscatter diffraction (EBSD), field emission gun (FE), cryo-SEM and energy-dispersive x-ray spectroscopy (EDS) with the SEM have become a powerful approaches for the characterisation of advanced crystalline materials. This review work related to different approaches of SEM can be very helpful to various industries like aerospace, nuclear, marine and power plant as it provides different techniques of SEM to investigate advanced materials in various service conditions.

**Keywords:** Material characterization, SEM, advanced material, EBSD, FESEM

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## 1. INTRODUCTION

By utilization of focused beams of electrons, SEM has become powerful tool for magnification purpose. SEM is useful to investigate surface topography, morphological information and elemental distribution by creating high resolution images by scanning of the surface of specimen and thus it becomes very valuable in technological advancement. The development of microscopes especially scanning electron microscopes has always been governed by one paradigm: their resolving power has to be enhanced. SEM is commonly used in the imaging of topographical properties and 90% of the research work is still dedicated to this characteristic or another of this application (Joy, 1997). Microstructure analysis is an important component for material characterization and has been an significant application of the SEM since energy dispersive X-ray spectrometers became available. SEM is a significant instrument that can deliver valuable information about the crystalline structure and various morphologies of advanced materials. However, if we see any object in three-dimensional (3D) view then it can create better understanding about that particular object. SEMs are limited to two dimensional images (2D) therefore it can provide only partial information about the materials. To understand truthfully the relationships between the phases and related properties, complex materials and morphologies are desirable to view unswervingly in 3D for better

investigation purpose. Recently, Yan et al. (2017) and Tafti et al. (2015) have demonstrated the single, multi view and hybrid techniques for 3D reconstruction of images of natural complex materials. Different approaches regarding SEM were attempted to identify the topography, morphology, chemical composition and crystallographic information of the materials. In addition, main limitation of SEMs are tendency to observe only solid and inorganic samples which are small enough to fit inside the testing chamber hence it is not suitable for liquid samples. So in general SEM, SEM-EDX, SEM-DIC, SEM-FIB and cryo-SEM are the different approaches during many research stated here for different applications. More categorised details based on different approaches and applications are stated in further section.

## 2. REVIEW OF SEM AND ITS DIFFERENT APPROACHES

SEM is used by many researchers in various areas as well as for understanding advanced materials. In this paper, different approaches are categorised to provide ready information on the basis of application point of view. Based on recent literature study related to engineering applications, it is observed that SEM is used for chemical composition, corrosion behavior, microstructure analysis, crack tendency and deformation study. Different approaches and applications of SEM considered in this work are mentioned in table 1.

**TABLE I: Summary of literature review**

Author(s)(year)	Variants of SEM	Material	Application of work	Critical observation/remark
Lafouresse et al. (2017)	Alternating current scanning electrochemical microscope	● 2024 aluminum alloy	● Mechanical degradation of various materials	● Corrosion rate
Tao et al. (2017)	Quanta 400 SEM	● Ti-6Al-4V	● Aerospace ● Industrial ● Marine	● Fracture analyses ● Hydrogen content during process (Microstructure changes)
Marusakova et al. (2017)	SEM vega TS 5130 XMT e-scan	● 800H alloy steel	● Mechanical degradation of various materials	● Microstructure analysis
Ding et al. (2017)	SEM-4800 Type II microscope	● W-Ni-Fe alloy	● National defense ● Civil industry	● Microstructure analysis ● Bending fracture morphology
Jiang et al. (2017)	JEOL SEM JSM6500F	● Advanced Ni-based superalloy	● Turbine disc application	● Fatigue crack initiation ● Propagation behaviour
Hemery et al. (2017)	JEOL 6100 SEM	● Bimodal Ti-6Al-4V	● Aerospace ● Industrial	● Detection of slip traces ● Characterization of the local crystalline orientation
Li et al. (2017)	SEM (FEI, QUANTA 450) based digital image correlation (DIC) method	● Nickel base alloy(GH4037)	● Aerospace ● Manufacturing ● Nuclear	● Plastic deformation
Mello et al. (2017)	FEI Philips XL-40 SEM	● Ni-based superalloy	● Aerospace ● Defence	● Deformation behaviour ● Crack initiation
Yan et al. (2017)	3D SEM hybrid reconstruction method	● 1200 grit structured abrasive material	● Bioscience ● Medical industries	● 3D representation of material ● Examination of natural materials ● Cannot relate to overlapping objects
Helmer et al. (2016)	SEM Helius 600i (FEI, Hillsboro, OR)	● Inconel 718	● Thermal power plants industries	● Microstructure analysis
Yan and Fan (2016)	JSM-5600 SEM	● High strength 2524 aluminum alloy	● Aerospace structural material used on the Boeing 777 and A380 aircrafts	● Fatigue crack initiation ● Propagation behaviour
Han et al. (2016)	SEM	● Ni-base single crystal (NBSX) superalloy	● High performance blades ● Disks	● Slip lines ● Crack initiations
Shi et al. (2016)	SEM (JSM-7500F PHILIPS)	● Ti(C, N)-Ni cermets	● Cutting tools for semi-finishing and finishing works on steel and cast iron	● Microstructure analysis ● Grain size distribution
Omrani et al. (2016)	Hitachi S-4800 FE-SEM	● Copper pins	● As study tool for improvisation of surface roughness and wear characteristics	● Topography of surface ● Wear mechanism
Sarikka et al. (2016)	SEM-EDS	● SA 508 ● AISI 309L/308L	● Nuclear power plants ● Steam generators ● Pressurizers	● Fracture analysis/Crack propagation ● Microstructure analysis
Holguin et al. (2015)	FEI helios nanoLab 600 SEM with a field emission gun	● AA2024-T3	● The aerospace and aircraft industries	● Chemical composition ● Corrosion rate
Yadav et al. (2015)	Hitachi S3400N SEM/EDX	● Mild steel	● Chemically exposed products	● Corrosion inhibition effect ● Surface morphology
Shang et al. (2015)	SEM	● A508 /alloy82/ SS 316 L	● Nuclear power plant	● Short fatigue crack propagation

Author(s)(year)	Variants of SEM	Material	Application of work	Critical observation/remark
Tafti et al. (2015)	3D SEM multi-view surface reconstruction	NA	• Bioscience     • Material     • Mechanical engineering	• 3D reconstruction of natural material     • Pose refinement and height evaluation     • It requires more sophisticated algorithms and computational time
Trdan and Grum (2014)	ZEISS LSM700 laser confocal scanning microscope	• AA6082-T651 alloy	• Aerospace     • Automotive     • Marine	• Characterization of the corrosion attack     • Surface pits observation
Wang et al. (2014)	FEI XL30 FEG-SEM	• A508 (LAS)-Alloy 52M	• Pressurized water reactors (PWRs)     • Nuclear pressure vessels	• Corrosion behaviour     • Chemical composition
Ming et al. (2014)	SEM/EDS (Philips XL30)	• SA508–309L/308L–316L domestic dissimilar metal welded joint	• Pressurized water reactors	• Microstructure analysis
Shao et al. (2013)	CS-3400 SEM	• TC 21 titanium alloy	• Structural components in the advanced aircraft industries	• Crack propogation     • Deformation behaviour     • Micro-cracks study
Guo et al. (2013)	SEM JEOL, JSM-6460 LV coupled with an EDS detector	• Austenitic – ferritic cast duplex stainless steel(CDSS)	• Primary coolant water pipes for PWR in nuclear power plants.	• Plastic deformation     • Phase identification
Hara et al. (2013)	Combination of FIB & SEM (arranged orthogonally)	• P122 Steel	• Complex microstructure analysis	• High-resolution and high-contrast SEM images can be obtained
Weidner et al. (2013)	MIRA 3X MU from TESCAN (SEM)	• Titanium aluminide (γ-TiAl) alloys	• Automotive     • Aerospace	• Influence of crystallographic orientation     • Deformation behaviour
Sturm et al. (2012)	Environmental SEM (FEI XL30 ESEM)	• A glass fibre reinforced polyamide 6, 6 (PA 66-GF)	• Manufacturing industries	• Chemical composition
Huttunen-Saarivirta et al. (2011)	FE-SEM Zeiss ULTRA plus	• Amine quinone polyimide as coating	• Improves the corrosion performance of galvanized steel	• Microstructure analysis of coating     • Corrosion behaviour
Richter et al. (2001)	Zeiss DSM 962 SEM	• 99.99% pure nickel	• Electrical equipments     • Industries	• Crack initiation     • Crack behavior at different location of ductile material
Blochwitz and Tirschler (2000)	SEM	• Polycrystalline nickel	• Aero gas turbines as critical rotating components.	• Crack opening displacement     • Deformation behaviour

This review paper is aimed to summarize various approaches of SEM related to industrial applications. Recently, it is also observed that many unconventional applications of SEM and its different approaches such as to identify chemical composition, corrosion behavior, wear mechanism and crack morphology. SEMs are large, exclusive and must be contained in an area free of any possible environmental disturbance or vibration intercession. Many attempts have been made to combine

these properties but specific attempt can be made to carry out research in more than two combination at a time to obtain all properties by single apparatus. With the proper use, in depth understanding and selection of appropriate approach can lead to better utilization of material productivity, reduction in failure chances, development of new materials with better understanding and advancement in process capabilities.



### 3. OUTCOMES OF LITERATURE REVIEW

From the above literature review of SEM and its various approaches, it is observed that many industries like aerospace, marine, nuclear stations, power plants and bio-science are using SEM for surface topography, morphology and crystalline characterisation. SEM is very beneficial tool to identify the corrosion behavior and crack initiation as well as its propagation. Effect of corrosion was investigated by comparing the alternating current scanning electrochemical microscope (AC-SECM) current profiles with scanning kelvin probe force microscopy (SKPFM) potential profiles of H-charged AA2024 samples (Lafouresse et al., 2017). An effort was made to characterize corrosion behavior as well as microstructure study of A508-Alloy 52M interface region (Wang et al., 2014). Hydrogen detection is the key element to study corrosion behavior hence many researchers are using SEM to study hydrogen content at microstructural level. SEM was used for studying crack opening displacements (COD) of short cracks in situ in SEM after cyclic deformation at constant plastic strain amplitude (Blochwitz and Tirschler, 2000). Chemical composition, surface imaging and corrosion behavior of additional coating on AA2024-T3 after layer formation was investigated by SEM (Holguin et al., 2015). Surface topography and chemical composition are the basic outcomes SEM micrographs. Some of the important works related to surface topography (Marusakova et al., 2017), microstructure (Ding et al., 2017), crack behavior (Richter et al., 2001), chemical composition and morphology aspects (Helmer et al., 2016; Tao et al., 2017; Shi et al., 2017; Trdan and Grum, 2014) of different materials such as 2024 aluminum alloy (Lafouresse et al., 2017), Inconel 718 (Helmer et al., 2017), P122 Steel (Hara et al., 2013) and TC 21 titanium alloy (Shao et al., 2013) can be carried out by SEM. So in general, SEM can be used in many ways to avoid failures and to predict material tendency. Here, Fig. 1 and Fig. 2 shows the summarised details of different approaches and applications of SEM in industries respectively.

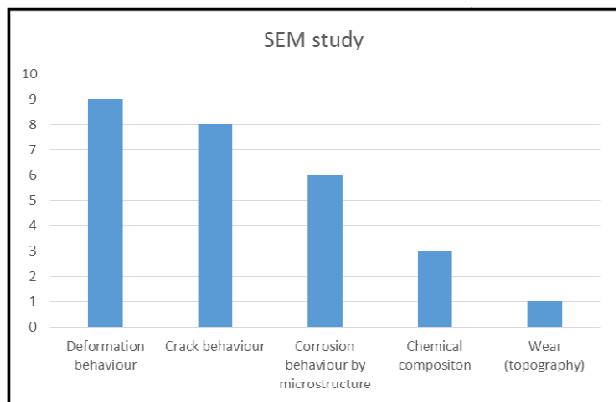


Fig. 1. Summary of approaches

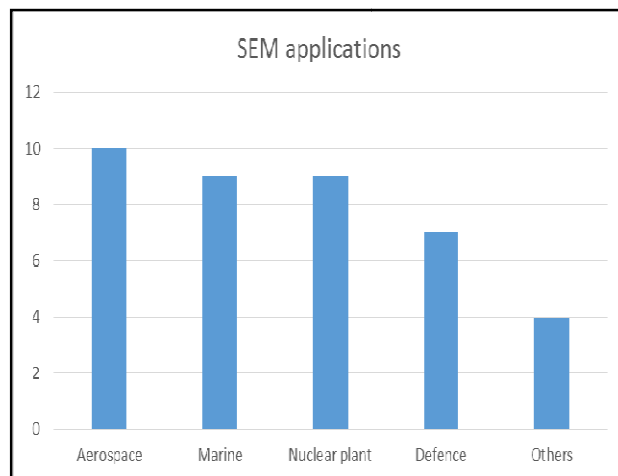


Fig. 2 Summary of applications

### 4. CONCLUDING REMARKS

With continuous evolvement of advance materials and processes with an aim of improvisation in service life, SEMs are very useful tools for understanding different materials and their behavior in particular targeted service environment. In general, SEMs can investigate surface topography, morphological properties, crack behavior, corrosion tendency, chemical composition, phase deformation and wear characteristics of advanced material used in aerospace, marine, nuclear and power plant industry. Further, SEMs are useful in medical, bio science and metallurgy related applications too. SEMs are only having limitations of sample preparation and specific size limitation of solid samples. Even though the risk is minimal, SEM operators and researchers are counselled to observe safety precautions. Further, it is suggested to carry out literature study regarding different approaches and advancement in microscopy, macroscopy and spectroscopy so it can help many researchers to select appropriate tool and technique for investigations.

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# Causes of Surface Defects during Surface Coating of Industrial Equipment by PTAW Welding Techniques

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**Abstract:** Now a days it become a very crucial task to improve the life of equipment working in harsh environment. Various superficial materials and alloys with the aid of surface treatments have been applied on the equipment used for oil, gas and petrochemicals industries. Overlay is the process of depositing corrosion and wear resistance material on the substrate material by application of welding technology. Failure of the part at the vicinity of weld region occurred due to improper welding techniques or defects in the weld region such as porosity, blowholes, undercut and irregular HAZ. Weldment characteristics like penetration, bead geometry, reinforcement, depth of penetration and HAZ which are extremely important characteristics for structural integrity and homogeneity of the joint in the case of overlay process. The required composition, bonding and surface characteristics plays a vital role to improve the life of hard surface deposited on the substrate material. The accurate control of process capabilities are important to avoid the failure of hard surfacing during working. Therefore, depositing hard surfaces on the material which serves in harsh working conditions need to access critically. In this respect there has been considerable interest to access the characteristics and properties of hardfacing. However, retention of exact characteristics with required mechanical and tribological properties are depends on the processing of material during hardfacing. Considering these all facts this article presents the probable causes of defects occurring during hard surfacing with PTAW technique by practical approach.

**Keywords:** Surface defects, overlay, hardfacing, PTAW, Stellite, cracks

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## 1. INTRODUCTION

Now a days, most of the parts of equipment used for power, alumina, nuclear and marine applications are failing due to abrasion, wear and corrosion. Abrasion, wear and corrosion are the processes which causes deterioration of material by gradual degradation and chemical reaction with their working environments. The possible threats of these deteriorations are components and machineries to fail during working. Moreover, these not only causes the aesthetic problems but also leads to cause the hazardous action, which increases the costs of repairing and rebuilding. In order to prevent the failure of components or equipment's used in various petrochemicals, marine, oil, nuclear, aerospace and power industries coating of superior material is applied on the parts which are directly exposing the aggressive environments (Madadi et. al, 2012). There are various methods to apply the coatings on the material; these techniques are probably based on characteristics and the behaviour of material in aggressive environments. The most common and practically applicable techniques to protect the material in very severe and harsh environments is to apply a metallic coating of outstanding resistant alloy on the materials (Bharath et. al, 2008). The selection of appropriate techniques plays a vital role in aggregating and maintaining the required characteristics of coating for long period. Moreover the parts are coated or repaired by superficial layer by the overlay techniques. Overlay is the

process of depositing corrosion and wear resistance material on the substrate material by application of welding technology. High energy density sources compromises rapid heating and successive quenching from the melt, resulting to fine microstructures and good improvement of mechanical, corrosion, or tribological properties (Bourithis et. al, 2002). Use of welding techniques can be more suitable as strong metallurgical bond being formed between the coating and the base materials. Hence, overlay processes are widely applied to enhance the corrosion and wear resistance of the substrate surface exposed to harsh working conditions, thus to improve and extend the service life of components.

The most commonly used welding techniques for the overlay are, submerged arc welding (SAW), tungsten inert gas welding or gas tungsten arc welding (TIG), oxyacetylene gas welding (OAW), plasma transferred arc welding (PTAW) and laser cladding (Balasubramanian et. al, 2009; Deng et. al, 2010). The application of these welding processes are commonly observed in petrochemical, chemical, steels, marine, power, oil and gas, alumina and aerospace industries (Deng et. al, 2010). Various researches on the coating characteristics and behaviour of material are going worldwide, to study the applicability and maintainability of these techniques for various kinds of material composition and pair. Failure of the part at the vicinity of weld region occurred due to

improper welding techniques or defects in the weld region such as porosity, blowholes, undercut and irregular heat affected zone (HAZ), weldment characteristics like penetration, bead geometry, reinforcement, and depth of penetration and HAZ which are extremely important characteristics for structural integrity and homogeneity of the joint in the case of overlay process. Superficial layers of the appropriate thickness free of cracks and with required mechanical and wear and tribocorrosion resistance properties may be obtained by suitable control of the process variables as the input process parameters plays a vital role in any welding processes.

The investigation of an overlay process is important to know how strongly certain parameters influence low distortion, less porosity and crack free surface with optimum value of hardness, penetration and reinforcement for a particular material composition. Considering these aspects it is necessary to understand the process and the causes of the defects. As, defects are the root causes for the equipment to fail because of perforation with only a small percent of weight loss of the entire structure. In this regard the process of welding overlay is studied with the effects of process parameters which are responsible for the surface defects and thus causing the failure of the part due to wear and tribocorrosion. The in-service modification and improvement of surface conditions of the equipment to avoid the failure is core area of investigation. In these respects, the causes of surface defects during surface coating of industrial equipment's by PTAW techniques are presented in this paper.

## 2. PTAW TECHNIQUE

The PTAW technique is a derivation of the plasma arc welding process. Use of non-consumable tungsten electrode is common in both the process and is located inside the torch. The PTAW uses powder as a filling material and inert gas, which is generally argon for its transportation to the arc area. PTAW technique has quite effectively been used as an outstanding surface alteration or treatment technique as a substitute to the other thermal spray processes (Bharath et. al, 2008; Deng et. al, 2010). Overlay obtained by the PTAW shows high quality, competitive wear and corrosion resistance and high retention of properties and characteristics of coating with better microstructural and stability of hardness at high temperature (Deng et. al, 2010). The PTAW overlays has a lower production cost and higher productivity compared to thermal sprayed coatings. The PTAW overlays are generally thicker than laser-induced overlays and there is a metallurgical bond between the substrate and the coating, improving their impact-resistance (Flores et. al, 2009a, b). Among the available techniques of overlay the most important differences lies in the welding efficiency and the weld plate dilution rates. The composition and properties of hardfacing are strongly influenced by the dilution obtained.

Control of dilution or penetration is important in overlay process, where typical low dilution is desirable (Balasubramanian et. al, 2009). The dilution obtain is much lesser in PTAW coatings. The PTAW presents high quality, competitive wear-resistance, and high stability of properties at high temperature (Deng et. al, 2010). The uses probable with PTAW are hardfacing and cladding to protect against severe conditions in service life like heat, abrasion, corrosion, erosion, adhesive and abrasive wear etc. It is also used to repair of worn out parts or build-up of mismatched parts. In practice, the parameters, which control the quality of the weld, are the gas flow rate (shield gas, plasma gas and carrier gas), the nozzle to work piece distance, the weld current and the welding speed.

Recently, PTAW technique has gain tremendous attraction for deposition of superior alloys on the substrate material to impart corrosion and wear resistance thus improves the service conditions. Superior alloying materials always imparted the surface modification; Co and Ni based alloys are applied in numerous industries, including chemical and fertilizer plants, nuclear and steam power plants, pressure vessel, as it is convenient and practical. In this regard the process of overlay is studied with the effect of process parameters which are responsible for the producing tough and harder coating without any defects. The main objectives of this paper are to reveal the exact causes of surface defects occurring during processing and to address the issues related to overlay related to PTAW. The causes of surface defects are evaluated by varying the process parameter between the allowable limits.

## 3. EXPERIMENTATIONS

To carry out the investigations, PTAW machine available with the KOSO India Pvt. Ltd. Ambad, Nashik, a valve manufacturing industry, made by Primo automation Ltd., is utilized which is fully automated. This technique has been in use for the surfacing of parts i.e. valve seat, collars, sleeve and couplings, employed for the surfacing of valves and components. Deposition is prepared on the surface of plate of thickness 16 mm in the form of multitrack layers by varying the process parameters. The electrode negative (DCEN) according to the welding process specification (WPS) ASME21, with position of groove 1G. Tungsten electrode size of 4 mm diameter (2% Throated Tungsten), torch orifice diameter 25mm, Industrially pure argon (99.99%) is used at a constant flow rate of 15 L/min for shielding, 2.5 L/min for centre, and 3 L/min for powder feeding.

The process parameters selected for the experimentations are, heat producing element i.e. transferred arc current (Amp), welding speed corresponding to travel speed (mm/min), filler material flow rate i.e. powder feed rate (gms/min), torch frequency i. e. oscillation speed (mm/min) and torch to workpiece distance i. e. stand-off distance

(mm). The effects of process parameters with defects obtained are observed and examined by visual inspections and dye penetration test. The substrate material and the surfacing alloy used for the experimentation is explained in following subsection.

### 3.1 Substrate material

The material used for the experimentation is based on the application of valve, pressure vessel, chemical processing industry etc. which should possess the weldability, good corrosion, wear and abrasion resistance properties. Material which is exposed to severe working conditions made up of, stainless steels, duplex stainless steel, Inconel, low alloy steels, high alloy steel and plain carbon steels etc. Stainless steels and Inconel of various grades are commonly employed for the manufacturing of valve, valve seats, collars and sleeves. However the area of base metal which is more susceptible to corrosion is coated by superficial layers of more corrosion resistant surfacing alloys. Most of the components applied for the marine environments are made up of duplex stainless steels, stainless steels and Inconel. Based on these points the material for the present investigation is selected as 316L stainless steels, which has widespread use in industries such as oil and gas pipelines, petrochemical chemical pumps, pressure vessels and chemical processing equipment.

### 3.2 Surfacing alloy

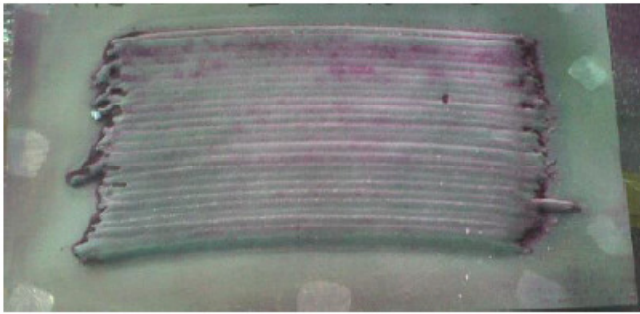
Cobalt based alloys are widely employed as wear-resistant hardfacing materials for combating wear in corrosive mediums and find applications in marine, gas, oil, petrochemicals, power, chemical, medical and food processing industries. Stellite alloy has nominal composition of Co - 28 Cr - 4W - 1.1C (wt. %). Stellite alloys which are commonly used as hardfacing materials in a variety of industrial applications, as they are known to possess high hardness at high temperature, good resistance to sliding wear under elevated contact pressure and good corrosion resistance. Stellite 6 is a cobalt-base alloy which is resistant to wear and corrosion and retains these properties at high temperatures (Madadi et. al, 2012). Stellite 6 is a useful hardfacing alloy in which chromium provides corrosion resistance while carbides add strength to the alloy (Singh et. al, 2014). From the literature it is found that Stellite 6 has excellent resistance to cavitation and corrosion, outstanding self-mating, anti-galling characteristics and it is used in valve, valve seats, plugs, pumps, bearings, shafts, erosion shields, rotors, etc.

## 4. RESULTS AND DISCUSSIONS

By varying the selected process parameters in between the available ranges the deposition is prepared in the form of layers on the substrate material. The weld bead geometry its appearance, surface irregularities and defects are examined by visual inspection and dye penetration test. Whereas, the

occurrences of crack generation on the surface of overlay are due to sudden change in temperature of surfaces. As the cooling rate changes, the Co based powder coating generates cracks on the surface of steels as shown in Fig. 2. Moreover, following inferences are drawn during operation and examination of overlay surface by dye penetration test.

1. For torch oscillation speed less than 450 mm/min, the bead appearance and contours were not so smooth and very narrow bead was obtained. When the oscillation speed was greater than 850 mm/min, wider bead width and smaller reinforcement height were observed. During the investigations it is observed that, higher torch oscillation frequency, the torch covers wider region of substrate material resulted in higher dilution with the gradual increase in width of deposition with torch oscillation frequency. Consequently at higher torch oscillation frequency, reinforcement decreases. As oscillation speed increases, the mean value of width of oscillation of torch also increases. In contrast, very thin layer of the deposited surface with spatter and blowholes are observed corresponding to high oscillation speed and lower powder feed rate. A very narrow and irregular weld bead and small deposition reinforcement is observed corresponding to the low oscillating speed. The chances of blowholes in the coating are higher at higher oscillation speed as shown in Fig. 1 than at lower oscillation speed.
2. If the powder feed rate was lower than 08 g/min, over melting of base metal and overheating of tungsten electrode were noticed. When the powder feed rate increases than 20 gm/min, the width and reinforcement of deposition increases. Also the weld bead formation was not smooth owing to incomplete melting of powders. Because, the amount of heat energy supplied at that instant is being utilised for melting of powder and forming a molten pool with possibly less melting of substrate material. This results less melting of substrate material, provided that the current supplied is sufficient to melt the powder supplied at that instant. It is also observed that, there is variation in deposition parameters with the powder feed rate and it is identified that cross-section area of deposition rises with the increase in powder feed rate and due to this the melting of substrate material decreases. Lower powder feed rate and higher current produces spatter and undercut on the surface with uneven layer of deposition as shown in Fig. 3. Whereas, higher powder feed rate reduces the melting of substrate material and causing less bonding in the deposited layer.
3. If the transferred arc current was less than 100 A, the incomplete melting of powders and lack of penetration is observed on the substrate surface. For



**Fig. 1 Overlay showing blowhole**



**Fig. 2 Overlay showing crack**



**Fig. 3 Overlay showing spatter and discontinuity**



**Fig. 4 Overlay showing spatter and less penetration and narrow bead width**



**Fig. 5 Overlay showing blowhole and uneven reinforcement**



**Fig. 6 Overlay showing blowhole and over melting of substrate at starting**

the transferred arc current greater than 180 A, the undercut and spatter are noticed on the weld bead surface. This is attributed due to the fact that the heat energy supplied for producing the arc at constrictor nozzle increases as transferred arc current. The prominent effects of heat supplied on melting of substrate materials is found in the investigations. With

the increasing current, the melting of substrate material increases leading to complete fusion of the powder supplied at that instant with the substrate surface causing higher deposition and undercuts. Consequently, at lower current the heat energy supplied is less causing incomplete melting of powder and less bonding with the overlaid material.



4. If the travel speed was less than 100 mm/min, there was an over deposition of weld metal and higher reinforcement height was observed. Travel speed corresponds to relative displacement of material surface per unit time to the torch or arc current. Higher travel speed greater than 180 mm/min reduces the time availability for deposition and thus producing very thin layer with zig zag pattern. Also less bonding and incomplete penetration is observed on the overlaid surface at higher travel speed. Which resulted in spatter and cut-off of deposition as shown in Fig. 4. Whereas, lower travel speed less than 100 mm/min shows over deposition of filler material as well as over melting of substrate surface resulted in deeper penetration and very thick weld bead with undercut and spatter as shown in Fig. 5. Thus, appropriate travel speed is necessary to create the bonding between substrate material and overlaid layer.
5. For stand-off distance less than 5 mm the bead appearance and contours were not so smooth and very narrow bead was obtained as shown in Fig. 6. When the stand-off distance was greater than 14 mm wider bead width and smaller reinforcement height with less melting of substrate material was observed. It is observed that the percentage melting of substrate decreases as the stand-off distance increases giving less concentration at particular point as lateral spread of arc concentration increases with stand-off distance. It is identified that, because of increase in arc length the constrictor arc diverge and the heat input supplied to the wider region of substrate material instead of directing on a lesser area. Which causes lower reinforcement and wider deposition width. Further, increase in stand-off distance, some amount of voltage rise takes place resulting in more heat input. It is also observed that the deposition width increases very slightly up to the mean level and again start to falls. Layer reinforcement also decreases with the increase in stand-off distance. This is attributed due to the fact that the change in stand-off distance did not vary the energy supplied to substrate material but the lateral spread of powder depositions increases due to changed diameter of energy density distribution from the plasma arc on the substrate material.

## 5. CONCLUSIONS

Surface overlay processes are widely used for the improvement in wear, tribocorrosion and mechanical properties of substrate surfaces which are exposed to severe environmental condition. Use of appropriate overlay technology is of prior importance to achieve desired properties of the surface. The realization of the economic advantage of increased wear resistance by providing a metal deposit on a relatively low cost substrate has spurred the growth of hardfacing over the last half century. Failure of

the components due to surface deterioration is the main focusing issue for the various industrial equipment's such as, power, marine, oil and chemical industry. The cost of failure of the equipment is not only related to the failure of the specific parts but it leads to decrease the productivity of the plant also in many cases it leads to hazardous action. To avoid the hazards due to failure of parts it is necessary to investigate the possible failure mechanism and to concentrate the root cause of the process. From the present investigations, it is observed plasma transferred arc welding overlay process is greatly affected by the influence of process parameters. The control of process parameters such as welding speed, powder feed rate, oscillation speed, transferred arc current and post and pre heat treatments are very important. In this investigation, an attempt is made to assess and investigate the causes of surface defects by proper controlling the input process parameters and systematic investigations. Now a days different types of stainless steels have been in use for the application where material exposes to severe condition, duplex stainless steel is widely used for various applications, tubing for heat exchanger, oil and gas, petrochemical, pulp and paper, and pollution control industries. The performance of a part is often determined by the properties of welded joints rather than those of main materials in welding processes. Therefore, it is very important to select proper welding process parameters employed in the process to improve weld qualities. The possible outcomes are useful for the industries where, surfacing of components are carried out by PTAW. Usually for power, oil and gas, petroleum industrial applications where, work related to steels rebuilding and refurbish or upgradation of properties takes place.

## 6. FUTURE SCOPE

The use of PTAW is tremendous in industry applications, however, the research on the technique considering applicability, effectiveness, efficiency, quality of overlay deposits and material applications are limited and very scared. Various superficial alloys can be implemented for the deposition, such as Stellite of various grades, Ni based alloy, Co base alloy, WC based alloys, Ti based alloy, TiN alloy etc., with the cheap base material. The superiority, effectiveness and applicability of various combination of materials need to be evaluated and examined by experimental investigations coupled with advanced techniques. Now a days different types of stainless steels have been in use for the application where material exposes to severe condition, duplex stainless steel is widely used for various applications, tubing for heat exchanger, oil and gas, petrochemical, pulp and paper, and pollution control industries. The microstructure, wear and abrasion resistance of the various material exposed to erosive, corrosive and abrasive media can be done by experimental investigation and in situ observations. It is very important to investigate the tribo-corrosion behavior of coating and to select the

proper welding process parameters employed for the process to improve weld qualities in the overlay. The applications of modern techniques, investigations and analysis plays a vital role to understand and evaluate the performance of the coating in the aggressive environment. Further investigations will be required in this field to explore the applicability and effectiveness of the process.

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# Taguchi Based Optimization to Minimize Tool Wear in Turning AISI 4340 Steel by Image Processing Method

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**Abstract:** The aim of this research paper is to minimize the tool wear of cutting tool by image processing during turning AISI 4340 steel. Taguchi  $L_{27}$  orthogonal array (OA) is used for conducting the experimentation. Cutting Environment, feed rate, nose radius, depth of cut and tool type are the input parameters for turning process. The output parameter is tool wear. Machine tool condition in terms of spindle vibration is considered as a noise factor (uncontrollable factor) to make design robust. Cutting speed is kept constant (210 m/min). Image processing module in MATLAB 13 software is used to measure the wear of tool. A special algorithm is designed for it. The results of ANOVA for Tool wear indicate that depth of cut is the most significant machining parameters in affecting the tool wear followed by feed rate, nose radius, cutting environment, and tool type. The main effect plot of S/N ratio, the optimal machining parameters are the cutting environment at level 3 ( $A_3 = MQL$ ), nose radius at level 3 ( $B_3 = 1.2$  mm), feed rate at level 3 ( $C_3 = 0.35$  mm/rev), depth of cut at level 1 ( $D_1 = 0.5$  mm), and tool type at level 3 ( $E_3 =$  coated (CVD)) or  $A_3B_3C_3D_1E_3$  in short. Tool wear is optimized up to 0.042 mm. Conformity test revealed that the predicted and experimental values of Surface roughness are within the range given by confidence interval.

**Keywords:** Optimization, Image processing, turning process, Taguchi, ANOVA

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## 1. INTRODUCTION

Demand of customers regarding quality of product and its production rate is increasing. To stand in the market with strong root manufactures have to fulfill this demand within the time. This can be achieved by the optimization of the process. Manufacturing process often involves optimization of machining parameters in order to improve product quality as well as to enhance productivity. In metal cutting process, especially turning, milling process, besides the basic cutting process parameters viz. cutting speed, feed rate, depth of cut, tool geometry, environment of cutting and the type of tool plays an important role to decide the performance of quality characteristics.

Hari Singh *et al* [1] (2005), in this paper, a design of experiment based approach is adopted to obtain the optimal setting of turning process parameter that may yield optimum tool wear. The predicted optimal values of flank wear width crater wear depth of coated carbide tool while machining the EN 24 steel are 0.172mm and 0.244 microns respectively. Shiv Sharma *et al* [2] (2014), this paper stated a Fuzzy logic modeling and multiple performance optimization in turning GFRP composites using desirability function analysis. The input variables are cutting speed, feed rate and depth of cut. The responses are surface roughness, metal removal rate and tool wear. The average

percentage error in fuzzy logic prediction obtained as 2.74 %, 12.67 % and 3.06 % for Ra, MMR and VB respectively. Debaprasanna Puhan *et al* [3] (2013), this paper stated hybrid approach for multi-response optimization of non-conventional machining on AISiCp MMC. The influence of discharge current, pulse duration, duty cycle, and flushing pressure on material removal rate, tool wear rate, surface roughness are studied. It is found that pulse duration, duty cycle, discharge current and flushing pressure contribute significantly to the multiple performance characteristics.

Hari Singh *et al* [4] (2003), Araştırma Makalesi *et al* [5] (2006), Nilrudra Mandal *et al* [18] (2011), these paper stated the effect of cutting speed, feed rate, depth of cut on flank wear, crater wear, tool wear during turning of EN24 steel, AISI 304 Austenite stainless steel, AISI 4340 steel respectively. Mr. Ballal Yuvaraj *et al* [6] (2012), this paper used the Taguchi method to find a specific range and combinations of turning parameters like cutting speed, feed rate and depth of cut to achieve optimal values of response variables like surface finish, tool wear, material removal rate in turning of Brake drum of FG 260 gray cast iron Material. It is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipments and facilities.

## 2. TAGUCHI PHILOSOPHY

Among the available methods, Taguchi design is one of the most powerful DOE methods for analyzing of experiments. It is widely recognized in many fields particularly in the development of new products and processes in quality control. The salient features of the method are as follows:

- It is a simple, efficient and systematic method to optimize product/process to improve the performance or reduce the cost.
- It helps arrive at the best parameters for the optimal conditions with the least number of analytical investigations.
- It is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipments and facilities.
- It includes the noise factor and makes the design robust.
- It is low cost experimentation

There are three Taguchi quality characteristics:

### 1. Smaller the better (SB) –

It is a non-negative measurable characteristic that has an ideal state or target of zero.

$$S/N = -10 \log \left( \left( \frac{1}{n} \right) \sum y^2 \right) \quad (1)$$

### 2. Nominal the best (NB) –

It is a measurable characteristic with a specific user defined target value.

$$S/N = -10 \log \left( \frac{\hat{y}}{s^2} y \right) \quad (2)$$

### 3. Higher the better (HB) –

It is a non-negative measurable characteristic that has an ideal state or target of infinity.

$$S/N = -10 \log \left( \left( \frac{1}{n} \right) \sum \frac{1}{y^2} \right) \quad (3)$$

## 3. MATERIAL AND EXPERIMENTATION

### 3.1 Test Specimen (Workpiece):

The work material used for the present study is AISI 4340 steel (diameter 50 mm and length 80 mm). In industries, this material is regularly used for manufacturing of hydraulic equipments like split bush. It is high tensile alloy steel well-known for its wear resistance properties and are suitable where high strength properties are required.

TABLE 1: Chemical composition of AISI 4340

C	SI	MN	S	P	Cr	Mo	Ni
0.36/ 0.47	0.10/ 0.35	0.45/ 0.70	0.040 max	0.035 max	1.00/ 1.40	0.20/ 0.35	1.30/ 1.70

### 3.2 Cutting Tool

The uncoated & coated carbides tool materials are used for improving the productivity. The coated carbide tool reduces wear and tear between tool insert and workpiece. In the present work, the uncoated and coated (Physical vapour deposition-PVD and Chemical vapour deposition-CVD) carbide inserts are used for turning AISI 4340 steel. In market the inserts of standard nose radius (from 0.4 to 1.6 mm) are available. ISO catalog Number of selected carbide inserts are CNMG120404, CNMG120408; and CNMG120412.

### 3.3 Experimentation

The experimentation was performed on CNC SPINNER15 lathe machine as shown in fig 3. Test pieces of size 50mm×80mm were cut from AISI 4340 steel bar. The five input variables used in this study were Cutting environment, Nose radius, Feed rate, Depth of cut and Tool type. Spindle vibration was taken as a noise factor. Cutting speed was kept constant.

TABLE 2: Process Parameters And Their Levels

Process Parameters	Level-1	Level-2	Level-3
Cutting Environment ( A )	Dry	Wet	MQL
Nose radius (mm) (B)	0.4	0.8	1.2
Feed rate (m/rev) (C)	0.15	0.25	0.35
Dept of cut (mm) (D)	0.5	1	1.5
Tool type (E)	Uncoated	PVD	CVD
Spindle vibration (m/s ² ) (NF)	1.7	4.3	6.9

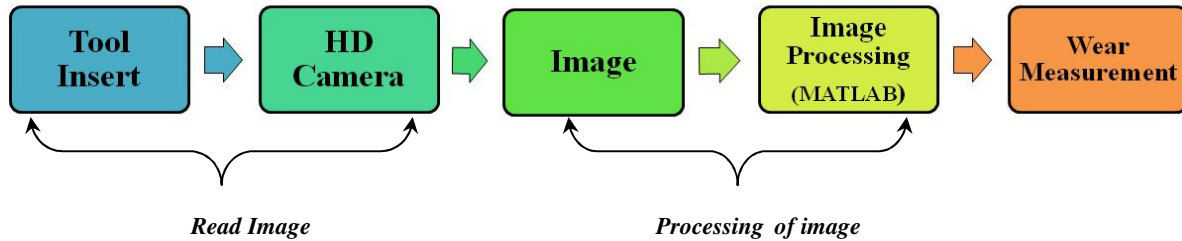


Fig. 1 Experimental Set Up

#### 4. MEASUREMENT OF TOOL WEAR

Cutting tool wear is measured by the image processing method in MATLAB software. This is a non conventional

method used for edge detection of tool. A special algorithm is made to detect the edge of the tool as shown below



##### 4.1 Steps of Wear Measurement

###### Step 1: Read the image:

The tool wear image is captured by high definition CCD camera and is fed to the image processing in MATLAB software as an input.

###### Step 2: Processing of image:

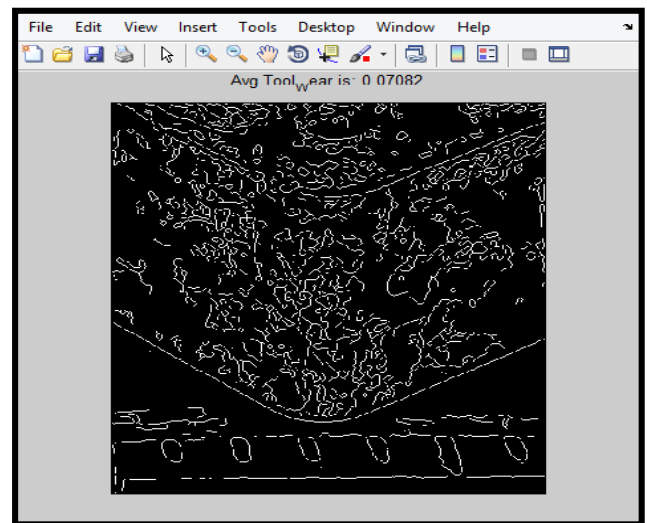
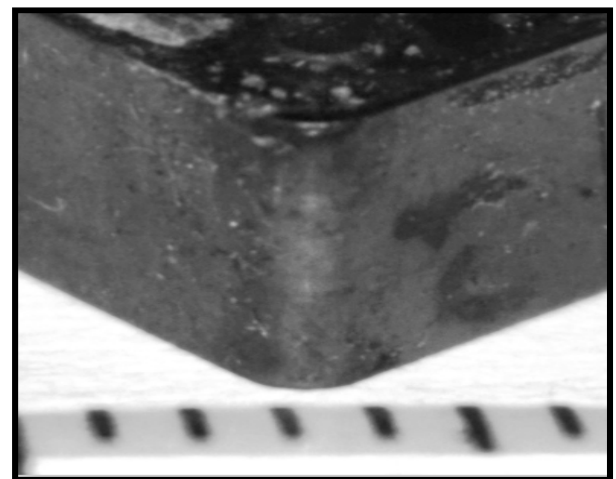
To enhance the good quality of the image, a self developed shadow removing algorithm written in MATLAB and the Canny edge detection algorithm in digital image processing toolbox for MATLAB was used for the segmentation of the wear area in the captured image.

- The Canny edge detection algorithm was preferred over other edge detection methods because of its double thresholds feature that allows detection of both strong and weak edges.
- The detected weak edges are included in the output only if they are connected to strong edges.
- The captured image is then saved in 'jpeg' format for further processing.
- Wear detection: edge detection technique is used for wear measurement.

There are various methods used for edge detection like Sobel, Prewitt, Robert; and Canny. Out of these methods, Canny is used as it gives the best performance. It also removes the noise present in the image.

###### Step 3: Wear measurement:

Wear measurement is done in terms of flank wear by using flank wear conditions. A new tool wear measurement technology is proposed and developed by image processing method. Software in MATLAB environment is developed to verify the suggested image. This method can extract the wear area based on a 2D image process algorithm.



**Fig. 2: Tool Wear Measurement By Edge Detection Technique**

The experiments are conducted as per Taguchi method and experimental data is collected for tool wear. Tool wear is measured for each level of spindle vibration and average value is taken as the final value shown in table

**TABLE 3: Experimental Data For Tool Wear And Its S/N Ratio**

Run	Tool Wear_NF ₁	Tool Wear_NF ₂	Tool Wear_NF ₃	Average Tool Wear	SN ratio Tool Wear
1	0.124	0.125	0.195	0.148	16.5912
2	0.087	0.087	0.136	0.103	19.7259
3	0.13	0.131	0.204	0.155	16.2009
4	0.102	0.102	0.16	0.121	18.3176
5	0.14	0.141	0.22	0.167	15.559
6	0.06	0.06	0.094	0.071	22.9192
7	0.145	0.146	0.228	0.173	15.2281
8	0.051	0.052	0.081	0.061	24.2507
9	0.066	0.066	0.103	0.078	22.1032
10	0.142	0.143	0.223	0.169	15.4207
11	0.104	0.105	0.163	0.124	18.1235
12	0.147	0.148	0.231	0.175	15.1231
13	0.119	0.12	0.187	0.142	16.9645
14	0.158	0.158	0.247	0.188	14.5329
15	0.078	0.078	0.122	0.093	20.6475
16	0.163	0.164	0.256	0.195	14.2181
17	0.069	0.069	0.108	0.082	21.7015
18	0.083	0.084	0.13	0.099	20.0913
19	0.114	0.114	0.178	0.136	17.3603
20	0.076	0.077	0.119	0.091	20.8517
21	0.119	0.12	0.187	0.142	16.9347
22	0.091	0.092	0.143	0.109	19.2653
23	0.129	0.13	0.203	0.154	16.2385
24	0.049	0.05	0.078	0.059	24.5961
25	0.135	0.136	0.212	0.161	15.8569
26	0.041	0.042	0.065	0.049	26.1409
27	0.055	0.056	0.087	0.066	23.6159

## 5. DATA ANALYSIS

Data analysis has been carried out by the procedural hierarchy as shown below.

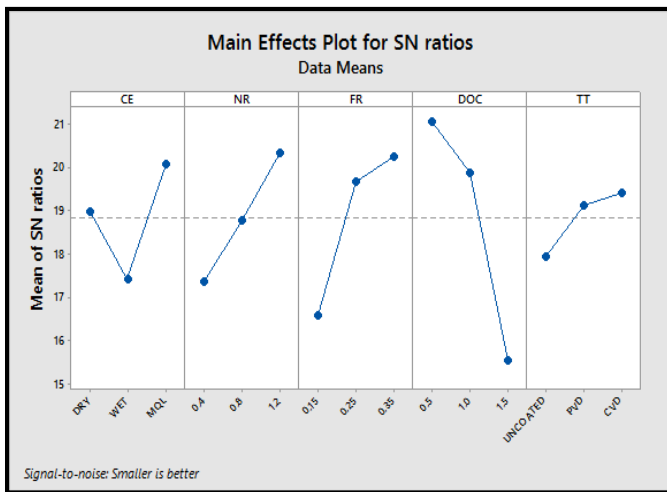
- Selection of equation for Signal-to-Noise ratio (S/N ratio) according to the objective of optimization. As the objective is to minimize the tool wear, therefore smaller the better (SB) equation (1) has been selected for S/N ratio.
- Computation of S/N ratio for each run. Tool wear with S/N ratio is listed in table 3.
- Calculations of response table for mean S/N ratio at each level of tool wear to identify the rank of level table 4 & fig 6
- Selection of optimal setting from mean S/N ratio.
- Computations of ANOVA to find the significance and contribution of each parameter on tool wear.
- Calculation of predicted value of tool wear by predicted additive model.
- Verification of predictive model by confirmatory test.

**TABLE 4: Response table for Signal to noise ratio**

Level	Cutting environment	Nose radius	Feed rate	Depth of cut	Tool type
1	-13.552	-14.612	-15.293	-11.651	-11.197
2	-11.860	-12.014	-12.620	-11.282	-11.926
3	-10.348	-9.134	-7.847	-12.827	-12.636
Delta	3.204	5.477	7.446	1.546	1.439
Rank	3	2	1	4	5

**TABLE 5: Analysis of variance for S/N**

Process parameters	DOF	SOS	MSOS	F	P	% Contribution
Cutting environment (A)	2	0.005111	0.002556	8.49	0.000	10.05
Nose radius (B)	2	0.004304	0.002152	7.15	0.000	8.46
Feed rate (C)	2	0.010758	0.005379	17.87	0.000	21.16
Depth of cut (D)	2	0.027686	0.013843	45.99	0.000	54.45
Tool type (E)	2	0.001754	0.000877	2.91	0.000	3.45
A * B	4	0.000011	0.000003	0.01	0.828	0.02
A * C	4	0.000009	0.000002	0.01	0.926	0.02
A * D	4	0.000012	0.000003	0.01	0.640	0.02
Residual Error	4	0.001204	0.000301			2.37
Total	26	0.050849				100.00



**Fig. 3: Main Effect Plot of Signal To Noise Ratio**

### 5.1 Predicted Value of Tool wear (mm)

Optimal value of output parameter can be predicted by additive model

$$\mu_{pred} = \bar{Y} + \sum (\bar{Y}_i - \bar{Y}) \quad (4)$$

$$\begin{aligned} \mu_{TW} &= Y_{TW} + (A_3 - Y_{TW}) + (B_3 - Y_{TW}) + (C_3 - Y_{TW}) + (D_1 - Y_{TW}) + (E_3 - Y_{TW}) \\ \mu_{TW} &= 0.123 + (0.107 - 0.123) + (0.107 - 0.123) + (0.104 - 0.123) + (0.097 - 0.123) + (0.115 - 0.123) \\ &= 0.0401 \text{ mm} \end{aligned}$$

Error variance  $V_e = 0.000301$

Therefore,

$$CI = \pm 0.018$$

The 95% confidence interval of the population is:  $[\mu_{TW} - CI] < \mu_{TW} < [\mu_{TW} + CI]$

$$0.0223 < 0.0401 < 0.0579$$

**TABLE 6: Confirmatory Experiments for Tool Wear (mm).**

Sample	Tool Wear (mm)		
	NF1 1.7 m/s ²	NF2 4.3 m/s ²	NF3 6.9 m/s ²
1	0.0338	0.0346	0.0588
2	0.0339	0.0368	0.0549
3	0.0342	0.0357	0.0568
Average	0.0340	0.0357	0.0568
Total Average	0.0422		

## RESULTS

The results of ANOVA for Tool wear indicate that depth of cut is the most significant machining parameters in affecting the tool wear followed by feed rate, nose radius, cutting environment, and tool type. Based on the above discussion and the main effect plot of S/N ratio, the optimal machining parameters are the cutting environment at level 3 ( $A_3 = \text{MQL}$ ), nose radius at level 3 ( $B_3 = 1.2 \text{ mm}$ ), feed rate at level 3 ( $C_3 = 0.35 \text{ mm/rev}$ ), depth of cut at level 1 ( $D_1 = 0.5 \text{ mm}$ ), and tool type at level 3 ( $E_3 = \text{coated (CVD)}$ ) or  $A_3B_3C_3D_1E_3$  in short

**TABLE 7: Values of Process Parameters at Optimum Level**

Process Parameters	Code	level1	level2	level3
Cutting Environment	A	DRY	WET	MQL
Nose radius(mm)	B	0.4	0.8	1.2
Feed rate (mm/rev)	C	0.15	0.25	0.35
Dept of cut (mm)	D	0.5	1	1.5
Tool type	E	Uncoated	PVD	CVD

## 6. CONCLUSION

The Taguchi method is successfully applied in this study to find optimal setting for turning AISI 4340 steel. The results are discussed as follows:

- 1) The single-objective problem is solved with the application of Taguchi Analysis.
- 2) Quality characteristic Tool Wear is optimized to 0.042 mm

- 3) Optimal parameter setting for turning AISI 4340 steel is ( $A_3 B_3 C_3 D_1$  and  $E_3$ ) i.e. cutting environment=MQL, nose radius=1.2 mm, feed rate =0.35 mm/rev, depth of cut = 1.5 mm, and PVD coated cutting tool.
- 4) Conformity test shows that the predicted and experimental values of Tool Wear are within the range given by confidence interval.

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# Advances in Abrasive Flow Machining Technology for Fine Finishing: A Review

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**Abstract:** The fine surface finish is one of the prime requirements in various finished components through conventional machining processes like grinding, lapping, polishing and super finishing processes. Many industries are striving hard to get the desired surface finish since they are using highly complex shaped and stringent property materials and this has increased the scope of research in non-conventional processes. Abrasive Flow Machining (AFM) is one of the non-conventional finishing processes in which a semi-solid medium consisting of a visco-elastic polymer and abrasive particles mixed in a definite proportion. This media is extruded under pressure through or across the surface to get the required finish. In this paper current research advances in abrasive flow machining are discussed thoroughly, also author has tried to identify the research gap in the past work. The review paper opens new research avenues for further work.

**Keywords:** Abrasive flow machining, Magnetic abrasive finishing, Magnetic abrasive flow machining, Magneto rheological abrasive flow finishing

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## 1. INTRODUCTION

Technologies in modern industries are getting highly advanced, thus the machining processes involved are required to be more precise and efficient to obtain a quality product whilst maintaining high productivity. Life and functionality of a product is directly influenced by its surface finish. Now-a-days, nonconventional materials like Titanium alloys, Tungsten, various composites etc. are used widely in industries because of their special properties such as high strength, high hardness, better wear resistance, high toughness etc. However these properties make them difficult to be machined. Various conventional finishing processes such as grinding, honing, lapping etc. are used in industries for long time, but they are limited to particular geometries and cannot be applicable to complex geometries and intricate profiles to machine to high level finish as required during the operation of these components. Some advanced finishing processes like AFM (Abrasive flow machining), MAF (Magnetic abrasive finishing), and CMP (Chemical mechanical polishing) etc. can be employed for finishing these materials (Jain, 2004). The material removal mechanisms of abrasive fine-finishing technology are quite different from those of grinding. In Abrasive fine-finishing technology the stock removal capability is far lower than grinding, and thus it is helpful in maintaining accurate dimensional accuracies. It does not utilize grinding wheels, and the cutting speed is significantly lower than in grinding (Fukuo et. Al. 2016). Extrude Hone Corporation of USA in 1960s developed the concept of AFM to finish aerospace components to the required accuracy. Today abrasive flow machining is considered as one of the best method for finishing of complex geometries not accessible by the

conventional finishing tools. Many researchers are consistently working in this are for the betterment of AFM process. This article includes detail review of current research trends in AFM process on the basis of Advanced setups of AFM process, Different combinations of Abrasive media and the applications of advanced setups in field of Agriculture, Engineering and biomedical applications.

## 2. ABRASIVE FLOW MACHINING

The mechanism of material removal in AFM is as follows:

- a. Initially, the material is ploughed by the fine abrasives that come in contact with the work material as they rub over the metal surface with high pressure. The material flow occurs in the direction of motion of abrasive particles as well as in lateral direction, resulting into the formation of lips.
- b. At the lips, work hardening is noticed due to the rubbing action of the continuous flowing abrasive particles which are also responsible for intense plastic flow with considerable stress concentration.
- c. The further flow of abrasive particle causes continued work hardening which results in embrittlement and fragmentation of the lips into microchips. (Gorana, Jain and Lal, 2006).

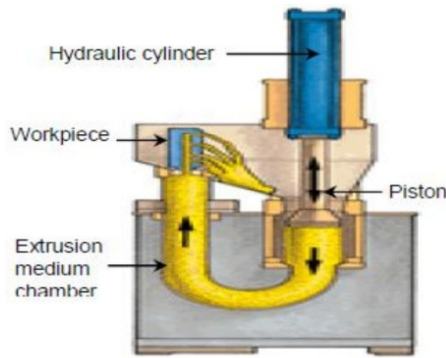
Abrasive flow machines are classified into 3 types based on motion of abrasive media.

1. One-way AFM: Abrasive media is forced in one direction as shown in Fig. 1(a) (Rhoades, Kohut and Nokovich, 1994).

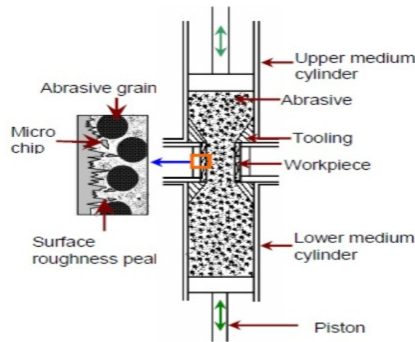


2. Two-way AFM: Abrasive media reciprocates to and fro as shown in Fig. 1(b) (Rhoades and Kohut, 1991).
3. Orbital AFM: Small orbital vibrations are applied to the work piece shown in Fig. 1(c) (Gilmore and Rhoades, 2001).

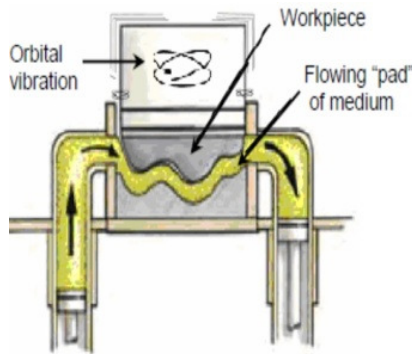
Abrasive flow machining is influenced by number of parameters which are classified as machine parameters, work piece parameters and medium parameters (Williams and Rajurkar, 1989). Some of the parameters are listed below.



(a) One way AFM process



(b) Two way AFM process



(c) Orbital AFM process

Fig. 1. Types of Abrasive flow machining processes

TABLE 1: AFM process parameters

Workpiece parameters	Machine Parameters	Medium Parameters
Hardness	Number of cycles	Type of abrasive
Material	Extrusion Pressure	Type of polymer carrier
Surface Texture	Flow Volume	Additives
Length of passage	Media flow speed	Concentration of abrasives

### 3. AN OVERVIEW OF DEVELOPMENTS IN ABRASIVE FLOW MACHINING SETUPS

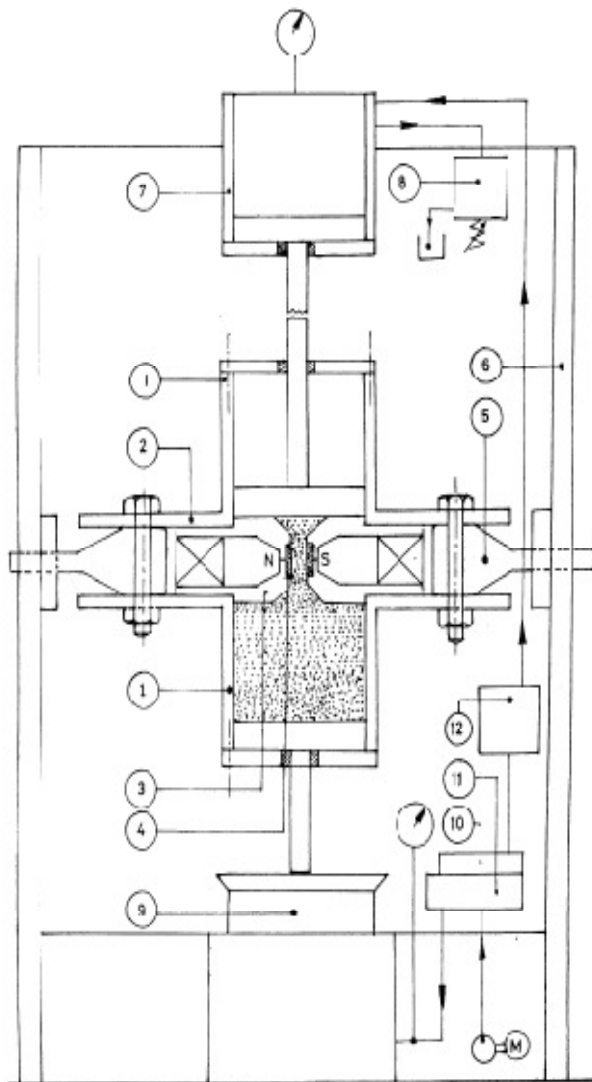
Abrasive flow machining has plenty of advantages listed as below:

- 1) Surface modification in texturing and topography.
- 2) Damage-free surface generation without a heat-affected zone.
- 3) Enhancement of surface integrity and the creation of compressive residual stresses in most of cases.
- 4) Improvement of geometrical accuracies, such as roundness, profile, etc.
- 5) Enhancement of visual factors such as uniformity, light reflection, brightness, etc. (Denkena, Kohler and Schindler, 2008).

Many researchers have investigated AFM and have concluded that the process is having low Material removal rate. To enhance the performance of AFM process many researchers have developed the hybrid machining processes in which various machining processes are combined with AFM process to achieve the higher MRR and required surface finish in lesser time. Some of the recently developed setups are highlighted in this section.

Singh and Shan, 2002 developed Magneto Abrasive Flow Machining (MAFM) process to improve the surface roughness by applying a magnetic field around the work piece. Magnetic flux density, volume flow rate, number of cycles, medium flow volume, abrasive grit size and abrasive concentration were the identified significant parameters. Improved surface finish and material removal rate is observed in MAFM over AFM.

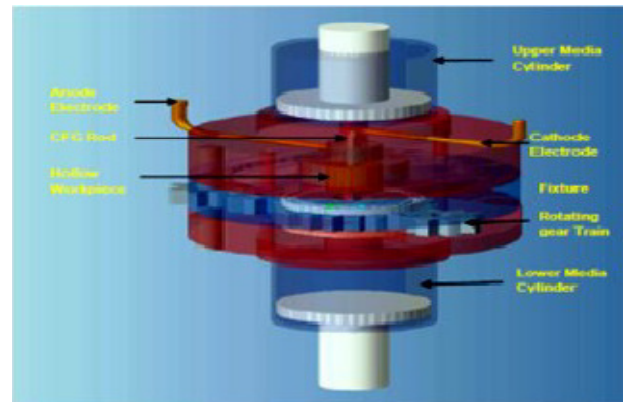




**Fig. 2. Magnetic abrasive flow machining**

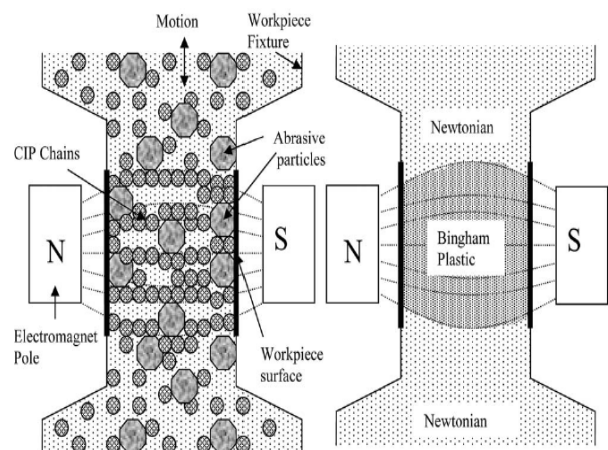
Main parts: (1) cylinder containing medium; (2) flange; (3) nylon fixture; (4) workpiece; (5) eye bolt; (6) hydraulic press; (7) auxiliary cylinder; (8) modular relief valve; (9) piston of hydraulic press; (10) directional control valve; (11) & (12) manifold blocks; (13) electromagnet. (Singh and Shan, 2002).

Rahul et al. [11] have developed Electrochemical and centrifugal force assisted abrasive flow machining process with an objective to enhance efficiency and quality of finish surface. The effects of parameters such as voltage, salt concentration, RPM etc. and constant parameters such as number of cycles, extrusion pressure on material removal has been investigated. The results depicted that better surface finish can be obtained with less extrusion pressure which can reduce damage of fragile parts. Also 70-80 % machining time can be reduced.



**Fig. 3. Hybrid electrochemical and centrifugal force assisted AFM process**

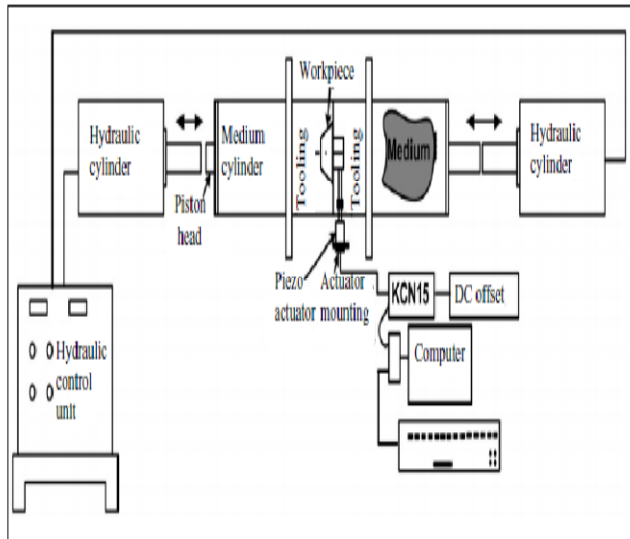
Jha and Jain developed Magnetorheological Abrasive Flow Finishing (MRAFF) process for finishing intricate details of a part. In this magnetorheological polishing fluid equipped with carbonyl iron powder and silicon carbide abrasives are mixed with viscoelastic base grease and mineral oil used to finish workpieces. 25-30 % improvement was observed in surface finish at high magnetic field application. The below mentioned figure is the schematic of magneto rheological abrasive flow finishing setup.



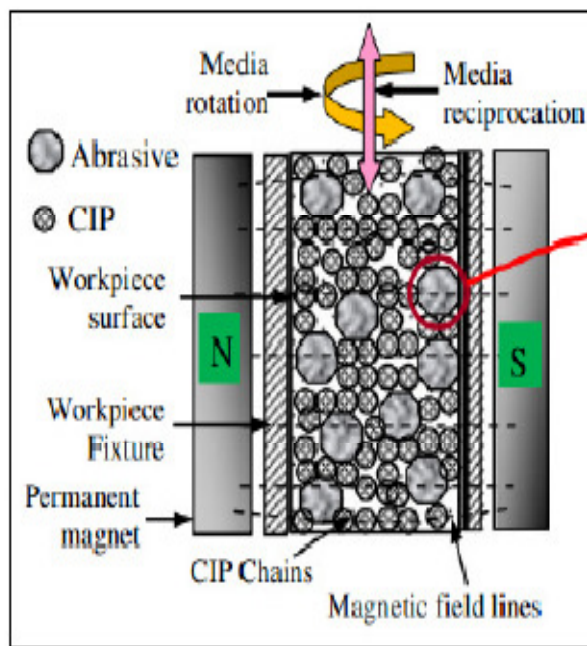
**Fig. 4. Magnetorheological abrasive flow finishing process, a) Mechanism of Magnetorheological abrasive flow finishing process; b) Change in rheological behaviour of MR-polishing fluid during finishing (Jha and Jain, 2004)**

Sharma et al. developed an Ultrasonic Assisted Abrasive Flow Machining (UAAFM) process in which workpiece is subjected to ultrasonic vibration perpendicular to the media flow direction. Fig. 5. shows the schematic diagram of UAAFM process. Das et al. proposed Rotational Magnetorheological Abrasive Flow Finishing (RMRAFF) process to enhance the surface finish of MRAFF process. In this process, a rotation and reciprocating motion is provided

to the abrasive medium by a rotating magnetic field and hydraulic unit as shown in Fig. 6. Smooth and mirror-like surfaces are observed in both stainless steel and brass workpieces.

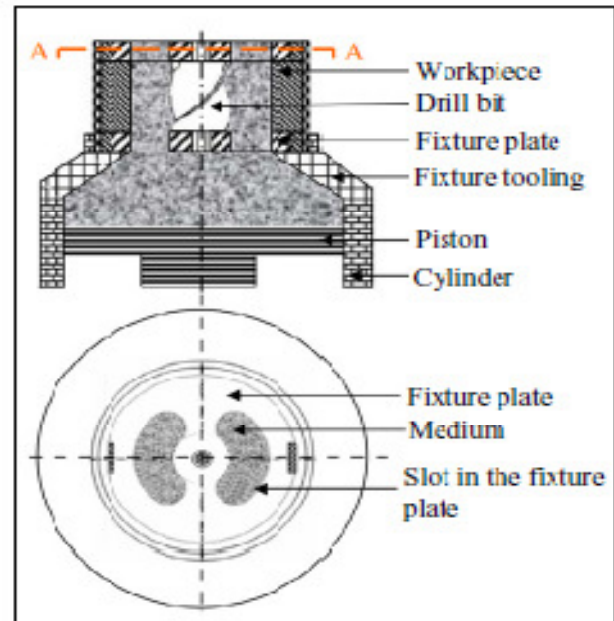


**Fig. 5. Schematic diagram of UAAFMM (Skarma et. al 2015)**



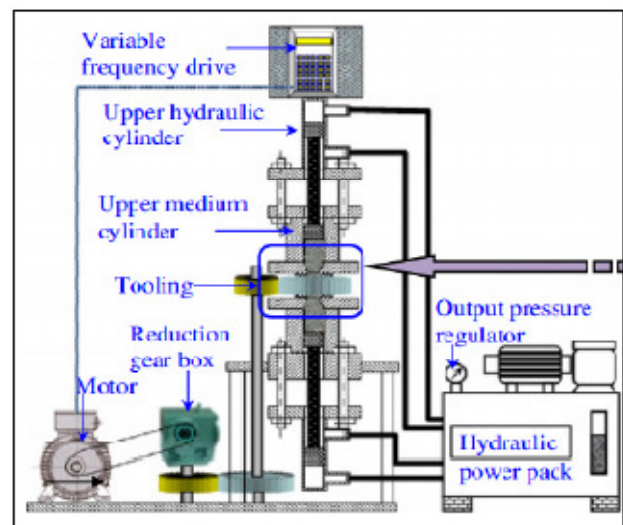
**Fig. 6. Schematic diagram of R-MRAFF**

Shankar et al. (Sankar, Mondal and Rajkumar, 2009) proposed a concept of rotating medium along the axis to enhance the surface finish and material removal rate. This process is known as Drill bit guided abrasive flow finishing (DBG-AFF) process as shown in figure 7.



**Fig. 7. Schematic diagram of DBG-AFF (Sankar, Mondal and Rajkumar, 2009)**

Shankar et al. (Sankar, Jain and Ramkumar, 2009) developed a model of Rotational Abrasive flow finishing (R-AFF) process. In this method the component to be finished is rotated at high speed in order to enhance the surface quality. Figure 8 shows the schematic diagram of R-AFF process.



**Fig. 8. Schematic diagram of R-AFF**

#### 4. DEVELOPMENT IN ABRASIVE MEDIA

Abrasive media is main constituent of the AFM process. The medium consists of viscoelastic polymer reinforced with the abrasive particles. In this viscoelastic polymer acts as a carrier medium and abrasive particles acts as a cutting

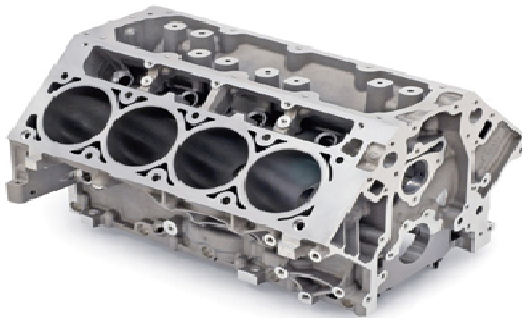
tool which removes the material from the workpiece. The commonly used polymer media are polyborosiloxane and silicone rubber and commonly used abrasives are silicon carbide, aluminum oxide, boron carbide and polycrystalline diamond (Santosh Kumar et al.) Researchers have tried to develop different alternatives to abrasive media which are highlighted in table below.

**TABLE 2. Different types Abrasive media**

Sr. No	Authors	Abrasives & its concentration	Polymer carrier	Results
1	Sankar et al. [18]	SiC	Styrene-Butadiene Rubber	MRR and surface finish is affected by Rheological properties of media
2	Wang et al. [19]	SiC with different mesh size (50%)	Silicon Rubber Silicon Rubber with additives	High quality finish was observed with silicon rubber with additives.
3	Kar et al. [20]	SiC with different mesh size (68%)	Natural Rubber Butyl Rubber	Butyl rubber showed better performance than Natural Rubber. Polymer media also affects the surface finish.

## 5. ADVANCED APPLICATIONS OF ABRASIVE FLOW MACHINING

Abrasive flow machining has wide range of applications. In case of cylinder block of engine, surfaces with low sliding friction and high wear resistance are present. Also precision mechanical components finished with mass finishing provide a low torque performance and a long service life. Silicon wafers or manifolds of engine also require high surface fineness; such components have to be finished on advanced options like abrasive flow machining.



**Fig. 9. Engine Cylinder Block**



**Fig. 10. Manifolds**

G. Venkatesh et al. (G. Venkatesh et al, 2015) has applied Ultrasonic assisted AFM process for finishing bevel gears made of EN8 steel. An analysis of the process has been presented with suitable illustrations. A finite element simulation of the behaviour of the medium during finishing of bevel gears using the UAAFM process has been presented. A 3D model was constructed to simulate the flow of medium through the outer wall of the gear tooth surface using computational fluid dynamics (CFD) approach. The velocity, pressure and temperature values along the length of the workpiece were computed for both UAAFM and the conventional AFM processes. Further, the effectiveness of the process was investigated through experimental trials by conducting a comparison study between classical AFM and UAAFM. Ultrasonic frequency, extrusion pressure, processing time and the media flow rate were considered as the input variables while improvements in surface finish and material removal were considered as the monitored outputs. Results concluded that improvements in surface roughness and material removal are significantly higher than those obtained with conventional abrasive flow machining. The work has also inferred that applied high frequency (ultrasonic) vibration to the workpiece has the maximum influence on the process responses among the variables considered.

The Navier–Stokes equation (Eq. (1)) was used for fluid flow simulation in order to define the fluid flow characteristics.

$$\rho \left( \frac{\partial u}{\partial t} + u \cdot \nabla u \right) = -\nabla p + \nabla \cdot T + f_i \quad (i)$$

where  $u$  is the velocity vector, m/s,  $\rho$  is the fluid density, kg/m³,  $p$  is the pressure, Pa,  $T$  is the component of total stress tensor, N/m²,  $f_i$  is the body forces (per unit volume) acting on the fluid, N/m³, and  $\nabla$  is the vector differential operator.

Milk deposits are the serious technical and economic problem for the dairy industry. Ikko Ihara et al. (Ikko Ihara

et.al. 2016) used Magnetic abrasive finishing process to produce highly finished inner surfaces of stainless steel tubes to compare to tubes with conventional inner surfaces. Deposition and cleaning tests were carried out using an experimental loop including the stainless steel tubes with different surface roughness profiles. Data showed that the smoothly finished inner surface ( $R_a = 0.037 \mu\text{m}$ ) of stainless steel tubes prepared by MAF significantly improved the cleanability of milk residues. The results indicated that the cleanability of non-protein components of milk residue is affected by surface roughness.

## 6. CONCLUSION

Abrasive flow machining uses visco-elastic polymer and abrasive particles mixed in a definite proportion. In this paper attempt has been made to review the published technical papers on AFM process. The paper comprises of three different sections- Advanced setups of AFM process, Different combinations of Abrasive media and the applications of advanced setups in field of Agriculture, Engineering and biomedical applications. From the above discussed literatures following things can be concluded.

- Following advanced experimental setups developed by the researchers are highlighted in this paper. Magneto Abrasive Flow Machining (MAFM), Hybrid electrochemical and centrifugal force assisted AFM process, Magneto rheological abrasive flow finishing process, Drill Bit Guided-Abrasive Flow Finishing (DBG-AFF); Rotational-Abrasive Flow Finishing (R-AFF) and Ultrasonic Assisted Abrasive Flow Machining (UAAFM) which can improve the surface finish of the machine components.
- Different abrasive media with various mesh size and polymer carrier are introduced. It is concluded that polymer carrier, abrasive media with its concentration affects the surface finish of material. Thus such different combinations of abrasive media and polymer carrier can be used rather than traditional abrasives like silicon carbide, aluminum oxide in order to get better surface finish.
- At the end of paper, some typical examples like machining of bevel gears and internal surface finishing of milk containers in dairy industry are discussed. Thus advance develop setups of AFM can be applied in various fields of engineering.

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# Casting Yield Improvement using Modeling and Simulation Technique

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**Abstract:** Yield is the ability of a foundry to manufacture acceptable casting in a cast effective manner. Improving yield offers many financial benefits to the foundry. Along with direct cost control, high yield is also associated with better quality and process control. By using casting simulation, an optimum gating system can be designed to improve the yield of the casting. This paper presents work on analysis of a real world industrial casting for yield improvement. A commercially available software AutoCast has been employed for this purpose. Further, design of experiments (DoE) technique has been used to predict the significant factors and its effect on casting yield and rejection. The modifications suggested in this paper resulted in 0.42% improvement in yield at box level. At the overall foundry level, 2.72% improvement in yield has been realized.

**Keywords:** Casting simulation. Gating design, Yield, Quality

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## 1. INTRODUCTION

Foundry industry is one of the oldest manufacturing industries. In the current scenario of global manufacturing, cost effectiveness and quality are crucial factors for survival of foundries. There is continuous pressure on foundries to supply castings at lower prices, shorter lead times with assured quality than ever before. The profit of a foundry is greatly influenced by the casting yield, which in turn is defined as the total weight of good casting expressed as a percentage of the total weight of metallic material melted to produce them. Yield is a measure of foundry's ability to manufacture saleable castings in cost effective manner achieving the required quality. Achieving a balance between yield, defect free casting and manufacturing cost is always a challenge for foundries. Involvement of several parameters related to casting design (i.e. size, shape complexity, weight, and section thickness), material and process (molding material, feeding and gating methods, feed aids etc.) makes it a challenging problem. Due to complexity of the process, it is challenging to alleviate the defects (such as shrinkage porosity, blow holes, incomplete filling). Proper gating/feeding system design is critical to eliminate these defects as well as improve the casting yield. The quality of casting can be predicted by casting simulation, and if any defects are observed can be corrected by suitable modification in the gating and feeding system. Many researchers reported that, about 90% of the defects in castings are due to improper design of gating and feeding system, and only 10% due to manufacturing problems. Thus, casting solidification simulation enables predicting and preventing potential problems in advance to achieve high yield at the desired quality level, and helps to develop the casting process in an optimal manner.

In the literature, various techniques such as design of experiments and casting simulation have been reported for defect analysis. A large number of experimental investigations linking gating parameters with casting quality have been carried out by researchers and foundry engineers over the past few decades. Several commercial tools (such as AutoCast, Z Cast etc.) have been developed to perform the casting simulation. It has been reported that casting yield increased from 56% to 72% eliminating the defects. Computer simulation minimizes the failure rate to a huge extent compared to manual trials. The simulations were used to predict the temperature distributions and solidification sequences in the casting to optimize the casting conditions. Casting simulation has become a powerful tool to visualize mould filling, solidification and cooling, and to predict the location of internal defects such as shrinkage porosity, sand inclusions, and cold shuts. Iron foundries use these varieties of methods and software for design of feeding systems. The application of casting simulation software in the foundries not only minimizes the wastages of resources required for final castings, but also improves / enhances the quality and yield of castings, which implies higher value addition and lower production cost.

In the current work, the simulation and experimental investigations are carried out on real life industrial casting of 'Case Transmission' to improve the yield. AutoCast one of the commercially available simulation software has been used for this purpose because of its availability and proven ability. The AutoCast comprises a suite of nine programs to perform various tasks associated with casting design. Each program comprises a set of modules for design, solid modeling, simulation, analysis and improvement. As a part of this study, existing process of manufacturing casting has been studied and few modifications have been done in

gating design for improving casting yield and quality. The influence of key process parameters on yield and quality (rejections) have been studied using Taguchi Techniques. Further, new gating system is proposed. The results of simulation have been validated through shop floor trials. In the next section, importance of yield has been explained. In the subsequent sections, overall methodology, results of experimentation and modifications done are explained in details.

## 2. IMPORTANCE OF YIELD

As mentioned earlier, yield is defined as the total weight of good, saleable castings expressed as a percentage of the total weight of metallic materials melted to produce them. It can be represented as,

$$Yield = \frac{\text{Total weight of good castings}}{\text{Total weight of metal melted}} \times 100$$

Actual yield of a foundry is always less than 100% because weight of the metal melted always exceeds that of the good quality castings dispatched. Other than material saving, improvement in yield also helps to reduce the costs associated with melting the metal (energy cost).

## 3. METHODOLOGY

The overall methodology for the current work is depicted in figure 1. The main steps in the current approach are:

1. Study the existing process and method
2. Simulation for existing method
3. Design of Experiments (DoE) and shop floor trials
4. Design modifications and shop floor validation

These steps are explained in next subsections.

STEP 1	STEP 2	STEP 3	STEP 4
<u>Study of existing process</u>	<u>Simulation for existing method</u>	<u>DoE and shop floor trials</u>	<u>Design modifications and shop floor validation</u>
-Part model     -Material     -Process parameters     -Methods design     -Existing defects	-Parting lines     -Cores     -Feeders     -Feedaids     -Gating system     -Mould cavity layout	-Selection of critical parameters     -Analysis of results     -Shop floor trials	-Modification in existing design     -Simulation and analysis of modified design (step 2 is repeated)     -Shop floor verification

**Fig. 1. Overall methodology**

### 3.1 Study of existing process

As mentioned earlier, Case Transmission Casting has been selected for yield improvement (please refer figure 2). The data pertaining to manufacturing the casting has been collected from the shop floor. Main parameters related to casting manufacturing are shown in table 1.



**Fig. 2. Case Transmission Casting**

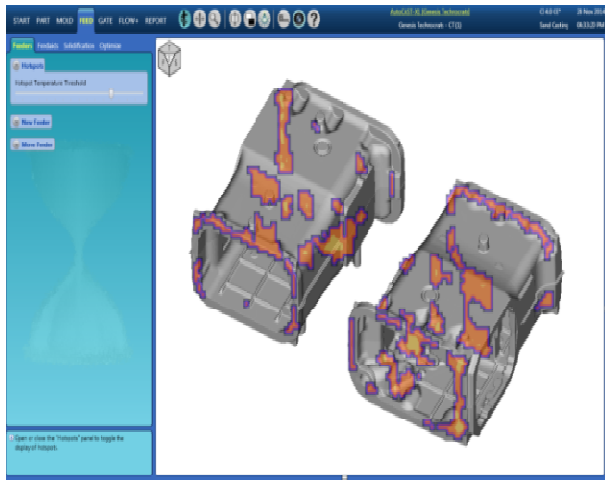
**TABLE 1: Component and process details**

<b>Grade of Metal : FG 220</b>	<b>Unit weight of casting: 61 kg</b>
Height of casting (C): 375 mm	Sand material: Green sand
Pouring temperature (T _p ): 1430 °C	Feeding time: 15 seconds
Liquidus temperature: 1250 °C	Solidus temperature: 1154 °C
Density of metal: 7200 kg/m ³	Total weight of casting in mould box: 61*2 = 122
Total dimensions of the mould box: 1200 mm x 800 mm x 725 mm	Type of gating system used: Hybrid Gating system
Shape of mould box: Rectangular	Mould layout : 2 castings per mould

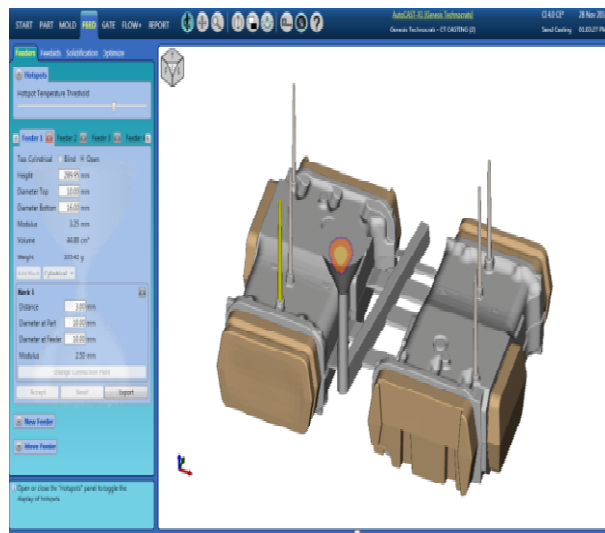
The feeding and gating design for existing method have also been studied and analysed in detail. The results of simulation for existing method are discussed in brief in the next subsection.

### 3.2 Simulation results for existing method

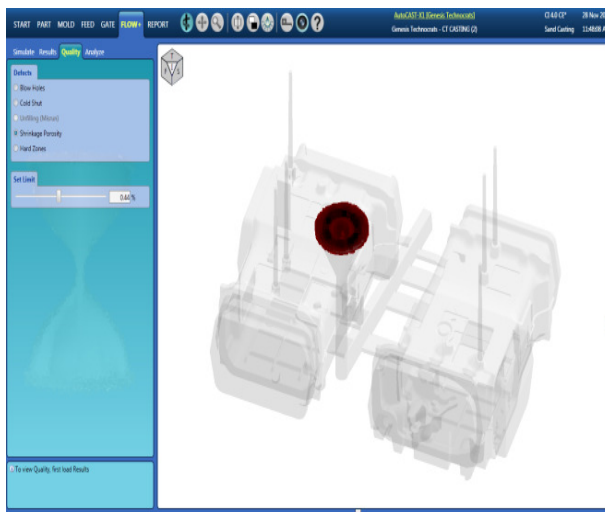
With the help of relevant information, the simulation trial was taken in order to analyse the defect for the existing gating system. In the existing system, a central sprue was used to feed both the cavities of two cavity mould. The pouring was done through a sprue which was connected to the runner. The runner was connected to mould by means of ingates (figure 3(b)). The results of simulation, especially for the defects related to solidification and blow holes are shown in figure 3(c) and 3(d).



(a)



(b)



(c)



(d)

**Fig. 3. Simulation results for existing system: (a) Massive section shows chances of hot spot (b) Hot spot absorbed in sprue cup (c) Shrinkage porosity absorbed in sprue cup (d) Prediction of blow holes**

The simulation result shows that, the hot spot is absorbed in the sprue cup and there is almost no shrinkage porosity in casting. However, blow holes have been predicted at the corner of castings (encircled in figure 4d). The results were verified with the real castings manufactured by the foundry. It was verified that, indeed there was a significant rejection (5-8%) because of blow holes in the foundry at the predicted location. The box yield with the existing design was 81.33%.

Further investigations were performed to improve the box yield and reduce the defects related to blow holes.

### 3.3 Modification in gating design and results:

Several experiments were conducted to study the effect of important parameters (pouring temperature, moisture content, compactibility and gating ratio) on yield and quality. The principles of Taguchi method were applied for conducting these experiments. L8 array has been used for experimentation. Based on discussions with domain experts, various levels of these parameters have been selected. These levels are shown in table 2. For each of the simulation run, the value of box yield, and potential defect have been predicted through software. In addition, shop floor trials were taken to determine rejections pertaining to these modifications. The data collected from these experiments is shown in table 3. Collected data have been analyzed using Taguchi method. Taguchi method uses signal to noise ratio in order to convert the trial result data into a value for the optimum setting analysis. The signal to noise ratio (SN) ratio main effect plots for various response variables are shown in figure 4. Minitab16 software has been used to study the influence of various parameters on yield and rejections.

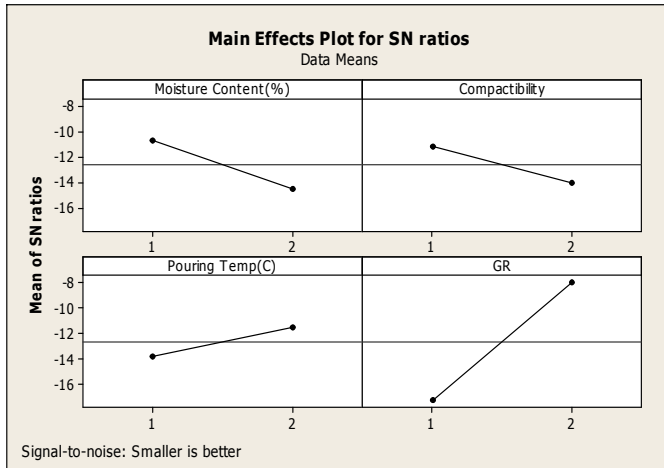


**TABLE 2: Factors and Levels**

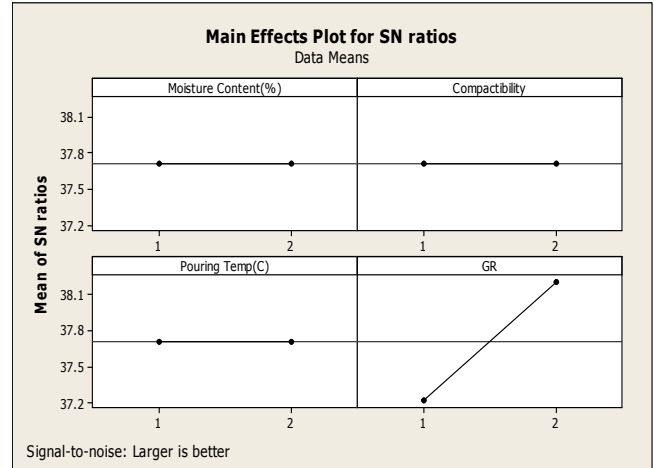
Process parameter	Level 1	Level 2
Moisture content (%)	3.2-3.5	3.5-3.8
Compactibility	38-40	40-42
Pouring temperature(°C)	1415-1425	1435-1445
Gating ratio	1:2:1.5	1:1.6:0.8

**TABLE 3: Standard L8 array for % rejection and yield along with S/N ratio values**

Moisture	Compactibility	Pouring temperature	Gating ratio	% Rejection	Yield	SNRA1	SNRA2
1	1	1	1	7.95	72.61	-18.0073	37.2199
1	1	2	2	1.13	81.33	-1.0616	38.2050
1	2	1	2	2.27	81.33	-7.1205	38.2050
1	2	2	1	6.81	72.61	-16.6629	37.2199
2	1	1	2	3.40	81.33	-10.6296	38.2050
2	1	2	1	5.68	72.61	-15.0870	37.2199
2	2	1	1	9.09	72.61	-19.1713	37.2199
2	2	2	2	4.54	81.33	-13.1411	38.2050



(a)



(b)

**Fig4: (a) S/N Main effects plot for % rejection (b) S/N Main effects plot for box yield**

As evident from the analysis, within the selected range, the most influencing parameter on rejection is the gating ratio, which accounts for (76.20%) of the total effect. All other parameters such as moisture content, compactibility and pouring temperature are less significant parameters. From SN ratio plots, it is clear that percentage rejection and box yield are minimum and maximum respectively at second level (1:1.6:0.8) of gating ratio, first level (3.2-3.5) of moisture content, first level (38-40) of compactibility and second level (1435-1445) of pouring temperature. Based on the above analysis, simulation results, inputs from domain

experts and some practical constraints from foundry, following improvement were proposed for yield and quality improvement:

- Runner bar modification: The height of the runner bar is reduced by 6mm as shown in figure 5. This resulted into 0.74 kg mass reduction.
- Addition of vent (encircled in figure 6(a)) for escaping the gases and prevent the blow holes (encircled in figure 6(d)).

The simulation study was carried out with these improvements. The results of this study are shown in figure 6. As evident from the figure, with proposed modifications the defects related to blow holes have been eliminated. In addition, decrease in runner bar size resulted in 0.42% improvement in box yield i.e. 0.74 kg saving of material.

With this method, trials were performed in shop floor and realized that defects pertaining to blow holes have been reduced to 1.5%. This reduction in defects also contributed to improvement in overall foundry yield. Thus, 2.72 % overall yield improvement has been observed in the foundry.

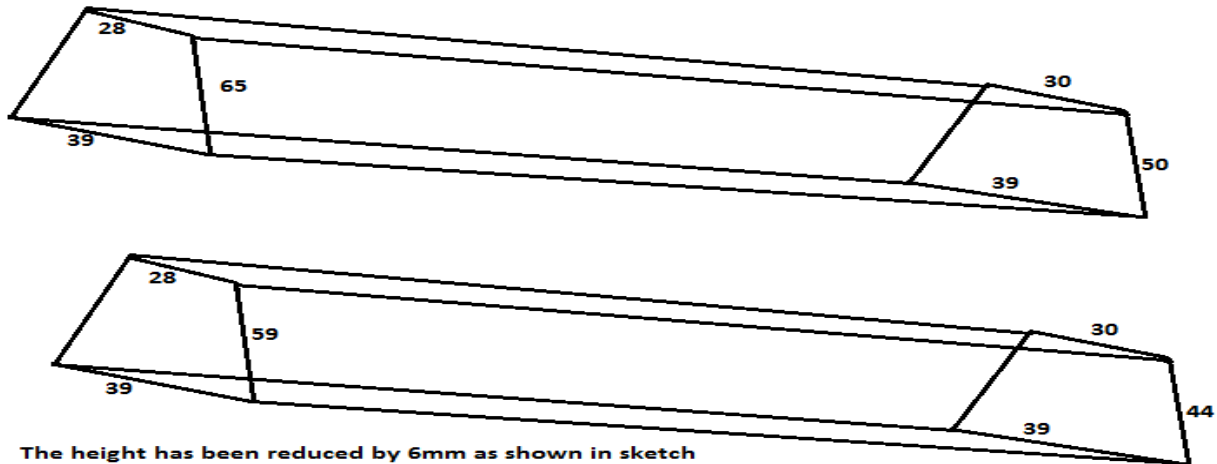


Fig 5: Change in the height of runner bar

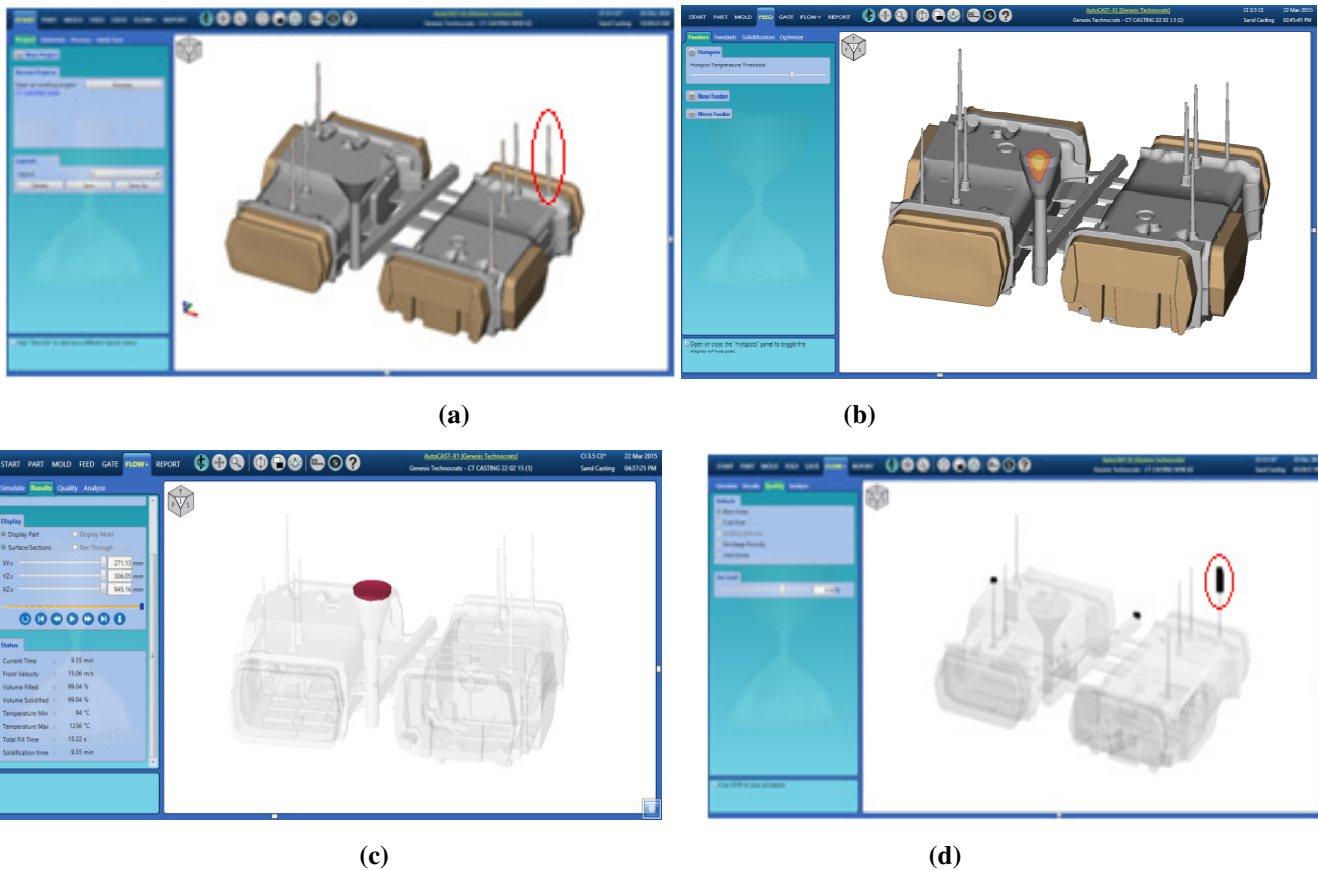


Fig. 6. Simulation results for modified system(a) Introducing additional flow off pin (b) Hot spot absorbed in sprue cup (c)Shrinkage porosity absorbed in sprue cup(d) Elimination of blow holes by flow off pin

#### 4. CONCLUSIONS

In this paper, an application of a simulation software program for mold filling, solidification analysis and yield improvement has been presented. The simulation program has been used to identify critical locations, filling pattern and solidification related problem areas in the casting. Based on the analysis of simulation and experimental results modifications in the gating system have been performed. These modifications resulted in 0.42 % improvement in yield at box level and 2.72% improvement in yield at overall foundry level. The higher improvement in yield at foundry level was realized because of reduction in rejection percentage. A significant benefits and savings have been realized by the foundry. These include savings in the costs associated with in metal, time, labor and energy. Further, experimental investigations were carried out to study the influence of various parameters on yield and quality, and analysis was done using Taguchi techniques. For the selected parameter levels, it was realized that percentage rejection and box yield are minimum and maximum at second level (1:1.6:0.8) of gating ratio, first level (3.2-3.5) of moisture content, first level (38-40) of compactibility and second level (1435-1445) of pouring temperature.

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# A Comprehensive Review of Optimisation Techniques Employed in Conventional Drilling Operation

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**Abstract:** Drilling is one of the most versatile conventional machining processes which is influenced by parameters such as spindle speed, feed rate, drilling depth, point angle, drill bit diameter, friction contact area ratio and tool type. A substantial number of research articles have been found dealing with the improvement in drilling performance of few widely used materials. The present review article presents a comprehensive review in deciding the optimised parameters through different optimisation techniques. The drilling of important and widely used engineering materials such as alloys, composites and ceramics has been addressed. Such studies are mainly focused on the different aspects of the drilling responses like surface roughness, thrust force, tool wear and associated physical phenomena. Such study can serve as a platform for the researchers in deciding the better-suited optimisation tool in the drilling of new and advanced materials.

**Keywords:** Optimisation techniques, Taguchi method, Drilling review, RSM.

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## 1. INTRODUCTION

The present scenario of increased customer awareness as well as the demand for the quality products leads to the rapid growth in huge competition amongst the producers globally. It resulted in the optimum usage of the resources and optimisation of the machining parameters. Nowadays, many conventional and non-conventional machining processes are used in the manufacturing of quality products using different materials. Still, use of the conventional machining operations covers a substantial portion of the total manufacturing processes. Out of the widely used conventional operations, drilling is the most versatile conventional machining operation used in machining of important engineering materials. Drilling operation covers around 40% of all conventional machining processes (Ku et al., 2010). In the present scenario, achieving better quality to improve the performance of the product is the basic necessity of every industry. However, many production industries encounter certain challenges such as dimensional as well as geometrical tolerances, better surface finish, high production rate and reduced tool wear. Increase in the metal removal rates leads to high productivity in machining operations. It is very difficult to balance the high metal removal rate and tight tolerance limits (Sheth et al., 2016). Therefore, optimisation of the drilling parameters becomes essential to improve the product quality and to reduce the overall cost of the product.

Drilling is a conventional machining operation of producing a cylindrical hole in a solid workpiece using a revolving tool called drill bit. The drilling of circular holes is one of the most common operations among all the machining processes and is more complex than other metal removal processes due to the access problem. The decline in

performance level under severe drilling conditions is another important difficulty associated with the drilling tools. The drills are buried in the workpiece, which obstructs the removal of chips away from the work zone (Huang and Lin, 2004). The quality of drilling operation is mainly influenced by the input parameter like feed rate, spindle speed, cutting speed, point angle of the drill bit, drill type and diameter of the drill bit. Since there are many parameters which affect the quality of drilling operation, it became necessary to use optimised drilling input parameters to get the improved quality of drilling products.

The present study presents a critical review of the important research articles dealing with the application of optimisation techniques in the drilling operation. Although the research in optimisation techniques is almost six decades old however the use of the optimisation techniques in drilling operation has been started 2004 onwards. The optimization of drilling parameter on different engineering material like aluminum alloy 6061 (Huang and Lin, 2004), LM25-based aluminum alloy reinforced with bonded silicon carbide of size 25  $\mu\text{m}$  (Haq et al., 2007), glass fiber reinforced plastic (Kilickap, 2010a), coir fibre-reinforced composites and other natural fibre-reinforced Composites (Jayabal and Natrajan, 2010), SUS 304 stainless steel (Ku et al., 2010), carbon fibre-reinforced epoxy composites (Shahrajabian and Farahnakian, 2013), copper (Kannan et al., 2014), Al/SiC/Al₂O₃ hybrid composite (Adalarasan and Santhanakumar, 2015), sandwich composite (steel and jute as reinforcements and polyester as the matrix material) (Vinayagamoorthy, 2016), wrought cast steel grade B (Sheth et al., 2016) have been performed using different optimization techniques for improving the quality of drilling operation. These articles also describe the in-built

drilling challenges with their possible solution during drilling of various materials.

The present extensive review has been performed in the framework of optimisation of input parameters of drilling for different materials to get the improved quality of drilled products. Such optimised conditions also help in reducing the machining time and related input attributes which eventually culminate in minimisation of the process costs. It can also be helpful in selection and alter the input drilling parameters depending upon the level of the quality products required. A brief explanation of different optimisation techniques used in drilling operation has been presented in the upcoming section. The main of this review article is to present a comparison between the various optimisation techniques purpose used and explore the better-suited optimisation technique for customising the drilling operation.

## 2. LITERATURE REVIEW

The engineering optimisation is the process of identifying the best combination of the input parameters for the customised output responses for a given material under prescribed working environment. Traditionally, the optimisation is often done manually which is an exhaustive and time-consuming process. The manual approach was time-consuming, and the searching ability of it is limited which often lead to sub-optimal solutions. In recent decades, some advanced optimisation approaches have been developed which offers more accurate results in less time than manual optimisation approaches. Normally, before the application of optimisation technique, corresponding mathematical modelling is developed for the output responses by using input parameters of the specific process. Response surface methodology (RSM), Taguchi method, Genetic algorithm, Particle swarm optimisation (PSO) and statistical-based multi-gene genetic programming are some of the extensively used optimisation techniques applied in customising the drilling operations.

### 2.1 Taguchi method

Taguchi method is one of the simplest and effective approaches for parametric design and experimental planning (Fisher, 1925). This method works by evaluating the signal and noise ratio for a set of experimental data for a specific manufacturing process. The term 'signal (S)' represents the desired value for the output characteristics whereas the term 'noise (N)' represents standard deviation for the output characteristic. Therefore, the signal to noise ratio (S/N ratio) is the ratio of the mean to the standard deviation for a particular output variable concerning. There are three types of S/N ratio depends on the type of characteristics; lower-the-better, higher-the-better and nominal-the-better. The selection of S/N ratio primarily depends on the nature of the response variable (Nian et al., 1999). Huang and Lin (2004) have used

Taguchi method based on Grey rational analysis for optimising the performance characteristics such as tool life, mean surface roughness and burr height in the drilling of Aluminum alloy 6061. They used a drill bit with coated deposition of TiN, TiAlN and CrN, spindle speed and feed rate as input parameters and had achieved better performance characteristics. Based on their study, they found that the multiple parameter characteristics are affected mostly by coated deposition. For optimal points of drilling parameter for tool life is CrN coated drill bit, spindle speed 2000 rpm, and feed rate 0.1 mm/rev. Haq et al. (2007) have used Taguchi method based on Grey relational analysis for optimising the performance characteristics such as cutting force, surface roughness and torque in the drilling of LM25-based aluminium alloy reinforced with bonded silicon carbide of size 25  $\mu\text{m}$ . They have used cutting speed, feed rate and point angle as input parameters. Kilickap (2010a) has used Taguchi method for optimisation of delamination in drilling of Glass fibre reinforced plastic. He has used cutting speed, feed rate and point angle as input parameters. He has found that Feed rate and cutting speed is the most influential parameter on the delamination. He concludes that lower cutting speed and feed rate is giving the better result of the delamination. Kilickap (2010b) has used Taguchi method based on RSM for optimisation of the burr height and surface roughness in the drilling of Al-7075. He has used cutting speed, feed rate and point angle as input parameters. RSM and Taguchi's method has been used for optimisation. Based on his study, he found Taguchi method as the most suitable technique to predict the burr height and the surface roughness. He found the lowest burr height and surface roughness occurred at a low feed rate, low cutting speed and high point angle. Ku et al. (2010) have used Taguchi method for optimisation of surface roughness (SR) and bushing length (BL) in drilling of SUS 304 stainless steel. They have used friction angle (FA), friction contact area ratio (FCAR), feed rate (FR) and spindle speed (SS) as input parameters. They have found that the bushing length of the drilled hole is nearly three times longer than the plate thickness under the optimal friction drilling condition, the friction angle and the spindle speed are significantly affecting surface roughness in thermal friction drilling. The optimal machining parameters regarding FA, FCAR, FR and SS for surface roughness in the drilling of SUS 304 stainless steel were 30°, 50%, 100 mm/min and 3600 rpm respectively. The friction contact area ratio is the only significant parameter for bushing length in thermal friction drilling as reported by them. Taskesen and Kutukde (2013) have used Taguchi method for optimisation of tool wear, and diametrical error in the drilling of B₄C reinforced Al-alloy. They have used spindle speed, feed rate and content of B₄C as input parameters. They have found that the tool wear increases with particle mass fraction and decreases with feed rate, the dimensional accuracy is negatively affected by the tool wear. They also found and reported the optimum values of

spindle speed, feed rate and content of B₄C regarding the minimal value of tool wear and diametrical error. Neseli (2014) has used Taguchi method for optimisation of thrust force and torque in the drilling of AISI 1040 steel. He has used cutting speed, feed rate and helix angle as input parameters. Based on his studies, feed rate and cutting speed were established as the dominant factor for thrust force and torque respectively. He found that the optimum values of input parameters are cutting speed 28 m/min, the feed rate 0.1 mm/rev and helix angle 30° which gives optimum thrust force of 1030 N and torque of 16.82 Nm. Siddiquee et al. (2014) have used Taguchi method in forminimising surface roughness in the drilling of AISI 321 austenitic steel using input parameters such as cutting fluid, spindle speed, feed rate and hole-depth. They have found that the surface roughness is mainly influenced by spindle speed, feed rate, cutting fluid and hole-depth and the surface roughness is improved by 131% from initial cutting parameter to the optimal cutting parameters. Minimum value of surface roughness (3.14 µm) was observed at spindle speed: 500 rpm, feed rate: 0.04 mm/s and hole-depth: 25 mm with the application of cutting fluid. Prasanna et al. (2014) have used Taguchi method based on gray rational analysis for optimisation of thrust force, overcut, circularity and taper in drilling of Ti-6Al-4V plate of 0.4 mm thickness. They have used spindle speed, feed rate and air pressure as input parameters. According to them spindle speed and air pressure comes out to be most significant parameters for the reduction of thrust force, overcut, circularity and taper angle. Abhishek et al. (2015) have used an integrated multi-response optimization philosophy by combining principal component analysis (PCA), fuzzy inference system (FIS) and Taguchi method for the minimization of thrust force, torque and entry/exit delamination factor in the drilling of carbon fiber-reinforced plastics. They have used spindle speed, feed rate and hole-depth as input parameters. They found that the highest drill speed, lowest feed and drill diameter is producing minimum torque, minimum thrust, and minimum delamination factor both at entry as well as exit. For minimum value of thrust force, torque and entry/exit delamination factor, the optimum value of input parameter are spindle speed 2800 rpm, feed rate 50 mm/min and hole-depth 6 mm. Kamboj et al. (2015) have used Taguchi method for minimizing the burr height and hole diameter error while drilling of AL6063/15%/SiC composites by using input parameters such as cutting speed, feed rate, step angle and cutting environment. According to them, the drilling-tool geometry plays an important role in the drilling of aluminium matrix composites. They found that feed rate and step angle have significant effect on burr height and hole diameter error, feed rate and step angle affect directly on burr height and hole diameter error while cutting speed effect inversely on burr height and hole diameter error. Balaji et al. (2016) have used Taguchi method for the optimisation of acceleration of drill bit vibration and

surface roughness in drilling of AISI 304 stainless steel for evaluation of tool life. They have used helix angle, feed rate and spindle speed as input parameters. They have observed increase in vibration of drill bit with the progression of the tool wear. According to them helix angle have significant effect on surface roughness and acceleration of drill vibration velocity with contribution of 78.22% and 50.02% respectively.

Akinciog˘ luet al. (2017) have used Taguchi method for optimising the surface roughness and thrust force in drilling of AISI D2 steel by using cryo-treated carbide drills. The input parameter was feed rate and cutting speed. They found that the feed rate is amost influential factor, affecting both surface roughnesses (66.97%) and thrust force (80.07%), the cryo-treated and tempered drills provide the lowest values of surface roughness and thrust force in comparison with the untreated and cryo-treated drills because of their improved wear resistance. They found the optimum values of input parameter were feed rate 0.063 mm/rev and cutting speed 60 m/min. AY et al. (2017) have used Taguchi method based on grey rational analysis for optimisation of surface roughness and cutting force in drilling of a hybrid Al/SiC/Gr metal matrix composites. They have used rate of graphite, feed rate and spindle speed as input parameters. They have taken Al/20%SiC/5%Gr, Al/20%SiC/7.5%Gr and Al/20%SiC/10%Gr as metal matrix composite composition. Based on their study they found that rate of graphite (10%), spindle speed (4500 rpm) and feed (0.1 mm/rev) were significant parameters for cutting force and surface roughness. Can and Ünüvar (2017) have used Taguchi method for the optimisation of surface roughness, thrust force and push out and peel up delamination behaviour in the drilling of glass fibre reinforced sheet mould compound composites. They have used feed rate, cutting speed and drill bit angle as input parameters. According to them, the drill bit angle was amost influential parameter for reduction of thrust force, delamination and surface roughness.

## 2.2 Genetic Algorithm

Genetic algorithm (GA) is a class of stochastic research methods that use techniques inspired by evolutionary biologies such as inheritance, mutation, selection and crossover. GA operates on a population of potential solutions applying the principle of survival of the fittest to produce better and better approximations to a solution. A major advantage of GA over other algorithms is that they need a type of primary guess about the solution, which is significantly effective on the result. GA needs a search range, which is presented according to the initial information of the physical properties. The evolution starts from a population of completely random individuals and occurs in generations. In each generation, the fitness of the whole population has been evaluated; multiple individuals are stochastically selected from the current population, and

mutated to form a new population. The new population is then used in the next iteration of the algorithm. This type of search does not fall into the optimum local values (Shahrajabian and Farahnakian, 2013).

Jayabal and Natrajan (2010) have used Nelder-mead and GA for optimisation of tool wear, thrust force and torque in the drilling of coir fibre-reinforced composites and other natural fibre-reinforced composites. They have used drill bit diameter, spindle speed and feed rate as input parameters. They have found that the accuracy of drill holes is increased when the tool is in good condition. They obtained minimum thrust force occurs at lower drill bit diameter, higher speed, and lower feed rate for coir fibre reinforced composites. For minimum tool wear the optimum value of input parameter is drill bit diameter is 6 mm, spindle speed is 600 rpm and feed rate 0.3 mm/rev. Kilickap et al. (2010c) have developed RSM based surface roughness mathematical model and have used GA optimisation in the drilling of AISI 1045. They have used cutting speed, feed rate and cutting environment as input parameters. They have found that cutting speed, feed rate and cutting environment were dominating parameters that contribute in minimising surface roughness. Kumar and Paulraj (2011) have used GA for optimisation of machining accuracy by minimising workpiece deformation in the drilling of Al-6061 and Al-7075. For this, support locations were optimized for minimum workpiece deflections, and with the help of optimised clamping forces, the highest locating accuracy was achieved. Shahrajabian and Farahnakian (2013) have developed RSM based mathematical model and have used GA for optimisation in the drilling of Carbon fibre-reinforced epoxy Composites. They have used spindle speed, feed and point angle as input parameters. They obtained minimum thrust force at tool point angle  $60^\circ$ , the minimum surface roughness when tool point angle  $140^\circ$  and the minimum delamination achieved at spindle speed 4000 rpm, tool point angle  $100^\circ$ . They found that feed rate is the most significant factor for thrust force, delamination and surface roughness. Kannan et al. (2014) have used GA and PSO in association with Artificial Neural Network modelling for optimisation of ovality, thrust force, surface roughness and machining time in the drilling of copper material. They have used spindle speed and feed rate as input parameters. They have found that the quality and production rate of drilling operation are significantly affected by spindle speed and feed rate. They conclude that compared with PSO, GA is giving better results for thrust force and surface roughness, compared with GA, PSO is giving better results for machining time and ovality. Shunmugesh and Panneerselvam (2016) have used Hybrid Particle swarm optimisation gravitational search algorithm (PSOGSA) and GA in the drilling of carbon fibre reinforced polymer for optimisation of thrust force, torque and surface roughness. They have used cutting speed, feed rate and drill bit type as input parameters. They have found that Artificial

Neural Network approach is effective in predicting the minimum value of thrust force, torque and surface roughness compared to the experimental values. The proposed hybrid algorithm, PSOGSA converges to the optimal solution with a lesser number of iterations compared to the GA.

### ***2.3 Response surface methodology based desirability function approach***

RSM is a collection of statistical and mathematical techniques useful for developing, improving and optimising processes. It uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations graphically represented as response surfaces (Khuri and Mukhopadhyay, 2010). In desirability-based approach, different solutions are obtained, and the solution with high desirability is preferred. Rajamohan and Palanikumar (2013) have used RSM based desirability function approach for optimisation of burr height, thrust force and surface roughness in the drilling of Al 356-aluminium alloy reinforced with silicon carbide of size 25 microns and mica of an average size of 45 microns. They have used spindle speed, feed rate and wt% of SiC as input parameters. They found that feed rate and speed are the dominating parameters that contribute to improving surface quality, reducing the thrust force and burr height. They obtained for the optimum value of burr height, thrust force and surface roughness with the optimised value spindle speed, feed rate and wt% of SiC as 1855 rpm, 50 mm/min and 15% respectively.

Meralet al. (2015) have used RSM based desirability function approach for optimisation of surface roughness, dimensional accuracy, circular deviation and axial misalignment between inlet and outlet of holes in the drilling of AISI 1050 Steel. They have used drill diameter, cutting speed, feed rate and tool type as input parameters. They concluded that the coated tools give better surface quality at high cutting speed and medium feed rate. However, good dimensional accuracy was achieved from lower cutting speed, medium feed rate and using the coated tool. They conclude that geometric precision of the holes is significantly affected by the cutting speed and feed rate, axial misalignment increased with decreasing drill diameter and decreased using the coated tool. For uncoated and coated tools, the most significant parameter on surface roughness is drill diameter whereas dimensional accuracy, circular as well as cylindrical deviations are significantly affected by cutting speed. Geier and Szalay (2017) have used RSM for optimisation of axial cutting force, delamination effect and surface roughness in drilling of uni-directional carbon fibre-reinforced polymers. They have used cutting speed, feed rate and screw pitch of the feeding helix as input parameters. They found the optimum value of cutting speed, feed rate and screw pitch of the feeding helix are 50 m/min, 0.049 mm/rev and 3 mm respectively.

## 2.4 Other techniques

Garg et al. (2014) have used statistical-based multi-gene genetic programming approach to optimise the burr height and average surface roughness. They took AISI 316 stainless steel as work material in drilling process. They have used cutting speed, feed rate, point angle, drill diameter and lip clearance angle as input parameters. Based on their finding, they opined that the feed rate, clearance angle and drill diameter are the most influencing parameters on burr height of the drilled component. Vinayagamoorthy (2016) has used Box-Behnken technique for optimisation of thrust force, surface roughness and damage at the entrance surface in the drilling of the sandwich composite which has steel and jute as reinforcements and polyester as the matrix material. According to him, spindle feed, point angle and tool diameter were the dominants affecting thrust force where as spindle speed and tool diameter were influencing the hole-wall roughness. Spindle speed, spindle feed and point angle have a major dominance on the profile damage of the drilled inner surface. He concluded for the output responses, the optimum value of input parameter are spindle speed 1070 rpm, feedrate 0.1 mm/rev, point angle 90° and tool diameter 8 mm which is very close to the obtained experimental result. Sheth et al. (2016) had used multi-objective optimisation based on Grey relational analysis to optimise cylindricity and perpendicularity of hole while drilling wrought cast steel grade B material. They have used spindle speed, feed rate and depth of cut as input parameters. They found that spindle speed and feed were significant parameters for cylindricity and perpendicularity. Minimal cylindricity is achieved at lower spindle speed, lower feed and moderate depth of cut, Minimal perpendicularity is achieved at higher spindle speed, lower feed and lower depth of cut.

## 3. SUMMARY OF THE REVIEW

The present review article summarises the application of different optimisation techniques adopted in the analysis of drilling parameters. The article also talks about the optimised drilling factors for different drilling responses. It also covers the comparisons between the results obtained from the different techniques for same drilling input parameter. From this review, it is evidently indicated that use of optimisation techniques results in achieving the substantial improvement in the surface integrity of the drilled products and which eventually results in a reduction in total cost of machining by selecting an optimal set of design and the operating parameters for the drilling operation. The optimisation techniques used the range of operating and design parameters to the objective of study, therefore by selecting optimum parameters set of corresponding optimum results can be obtained. From this article, it is observed that the comparison of the various optimisation techniques either used the single or in combination

give the close values as compared to the experimental findings.

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# Process Failure Mode and Effect Analysis of Hot Rolled Pickled Steel Strip

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**Abstract:** The Process FMEA (PFMEA) Technique is used at keshav Metal pvt. Ltd. Waluj, (MIDC), Aurangabad (M.S.) for identifying potential Failures of Hot Rolled pickled Steel Strip. The study present an effective tool for solving the problem of Manufacturing Industry by executing process FMEA with proposed process control practices. This study help to identify and eliminate current and potential problems from a manufacturing process of Hot Rolled Pickled Steel Strip in the company through the application of Failure Mode and Effects Analysis (FMEA).The various possible causes of failure and their effects along with the prevention are discussed in this work. Severity values, Occurrence number, Detection and Risk Priority Number (RPN) are some parameters, which need to be determined. Furthermore, some actions are proposed which require to be taken as quickly as possible to avoid potential risks which aid to improve efficiency and effectiveness of Hot Rolled Pickled Steel Strip processes and increase the customer satisfaction. The prevention suggested can considerably decrease the loss to the industry in term of both money, time and quality.

**Keywords:** Ishikawa diagram, Process FMEA (PFMEA), Pickling Process, Risk Priority Number (RPN)

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## 1. INTRODUCTION

Failure Mode and Effect Analysis (FMEA) is a process improvement tool to analyze and control the potential impacts from failures. from the FMEA practice it is expected to prevent the possible failures from a product or system after it is implemented. In such a way engineer can improve process by controlling the causes of failures or limiting their negative effects.

Failure mode and effects analysis (FMEA) is commonly defined as “a systematic process for identifying potential design and process failures before they occur, with the intent to eliminate them or minimize the risk associated with them”. The FMEA technique was first reported in the 1920s but its use has only been significantly documented since the early 1960s. It was developed in the USA in the 1960s by national aeronautics space agency (NASA) as a means of addressing a way to improve the reliability of military equipment.

Failure Mode and Effect Analysis is used to identify and analyzed: (a) all possible failure modes in the system/process (b) Effects of these failure modes on the system and (c) how to avoid these failure and/or moderate the effect of the failure system. FMEA is step by step methodology to identifying all potential failure in the process. Effect Analysis refers to studying the consequences or impact of those failures. The advantages of undertaking a process FMEA is to continuously develop product and process consistency thereby increasing customer satisfaction.

Demand on high surface quality cold sheet has been increased sharply in recent ten years because of rapid increase in auto industry. With the progress of hot rolling and cold rolling technologies. The scale must be removed previous to the cold rolling process, since it may produce operative problems and qualitative defects in the material. Effective scale removal is essential for the success, not only of cold rolling, but also of the subsequent annealing and coating operations (Lecourt, 1996). In order to get rid of these oxides, the steel strip is submitted to a critical process called pickling.

During the hot rolling or heat treatment of steel, oxygen from the atmosphere reacts with the surface iron to form a crust that is made up of oxides of iron. This crust is known as scale and need to be removed before steel is further processed in cold rolling mill. Non removal of scale will have the following detrimental effects.

- Scale not only give bad appearance to the product but also accelerate corrosion
- During cold rolling of the strip scale patches affects the reduction with the possibility of the skidding of rolls. Effective scale removal is essential for the success of not only for cold rolling but also of subsequent annealing and coating operations.
- During cold rolling and annealing the scale will produce a dirty surface and cause the rusting of the strip
- During coating of the strip, presence of scale causes poor to total adhesion failure.

## 2. BRIEF ABOUT CASE INDUSTRY

Keshav Metal Pvt. Ltd.-A leading Manufacturer of Hot Rolled Pickled and Cold Rolled Closed Annealed (CRCA) steel strip coils. The motto of the company is to enhance the customer satisfaction by processing and providing Cold Rolled Steel Strip and HR coils of agreed quality on committed Time.

Keshav Metal Pvt. Ltd company came in to existence in 1999 to cater the demand of CRCA strip flat products of mild steel for quality conscious customer. Coils/strip produced by Keshav Metal Pvt. Ltd are used in

Automobiles, pipes & tubes industries, furniture, Rolling shutters, Architectural utilities, and for specialized applications. Keshav Metal Pvt. Ltd. is situated at MIDC area Waluj, Aurangabad, Maharashtra, India

### 2.1 Formation of Improvement Group

To be able to measure, measure, analyze and improve the current situation there is a need of process knowledge. Thus it is decided to form an improvement group containing a variety of competences (sanders D. 2000). The group consists of production engineer, Quality Manager and operators.

## 3. PROCESS FLOW DIAGRAM

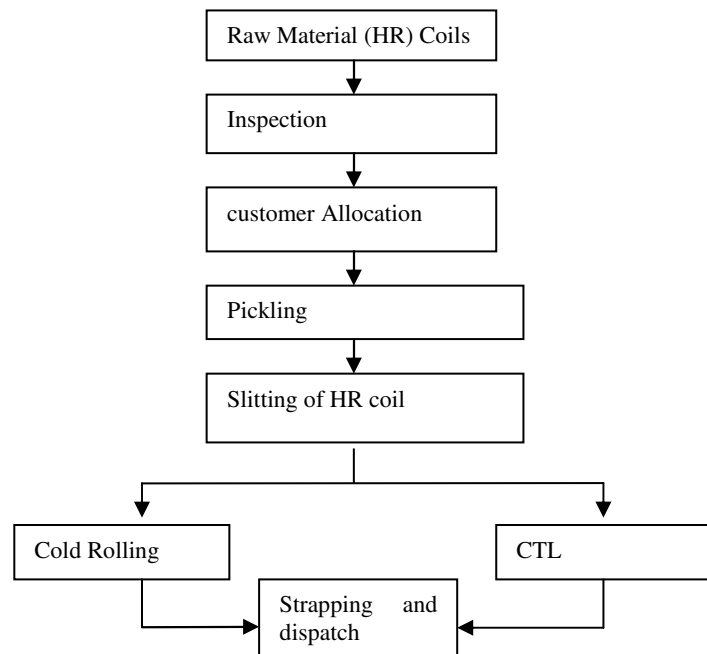


Fig. 1. Flow chart for HR Pickled Steel Strip Process

## 4. PROCESS FMEA

The process FMEA was carried out to detect the possible failure mode related to the manufacturing of HR Pickled and Cold Rolled Closed Annealed (CRCA) steel strip operation and prioritizes among them. When working with FMEA the starting point was the process map.

The improvement and quality group carried out the tool by looking the process flow diagram and discussed on the each process. And find out the possible failure modes in each process and gives them the Risk Priority Number (RPN).

The potential failure mode, cause and their effects shown in the FMEA sheet and various types defect and the origin of these defects are explained here in brief.

TABLE 1: Process function and potential failure mode

Process function	Potential failure mode
Pickling	Black scale on surface
	Rust on surface
	Scratch mark
	Under pickling
HR Slitting	Width Undersize
	Width Oversize
	Burr
	Cutter Mark
Rolling	Thickness Undersize
	Thickness oversize
	Skidding mark

### 1) Rusty patches

**Definition:** Corrosion products of iron appears in the form of reddish yellow to black patch on the strip

**Cause of formation:** presence of oil or emulsion carry over on the strip surface promoted by temperature fluctuations, high air humidity and long storage time or delay in next process.

### 2) Black Scale

**Definition:** These are permanent marks that appear on the strip after Pickling.

**Cause of formation:** low acid concentration or weak acid strength during the pickling process. The black Scale on the coil surface are also due to the impurities in the Acid

### 3) Roll mark

**Definition:** They are indentation or depression on the strip of regular form which occur periodically.

**Cause of formation:** foreign particles present between rolls. Improper cleaning of roll and roll grinding.

### 4) Coolant patch

**Definition:** These are Permanent mark that appear on the strip after cold rolling.

**Cause of formation:** Coolant used during rolling are not removed completely.

### 5) Rolled in scale

**Definition:** Scales which are not removed during pickling and is rolled into the surface during cold rolling operation.

**Cause of formation:** Inadequate preliminary de-scaling or pickling of hot strip

**6) Pickling defect:** During the pickling process, the under pickling and over pickling defects are usually the direct results of lack of control over process variables including acid concentrations, Solution temperature and contact time deriving from pickling line speed.

**7) Over pickling:** Pickling line must be maintained as per SOP Pickling tank acid concentration, Hydrogen absorption in sheet and temperature of the pickling bath. Line should not be stopped longer during the pickling process.

## 5. SELECTION OF RANKING

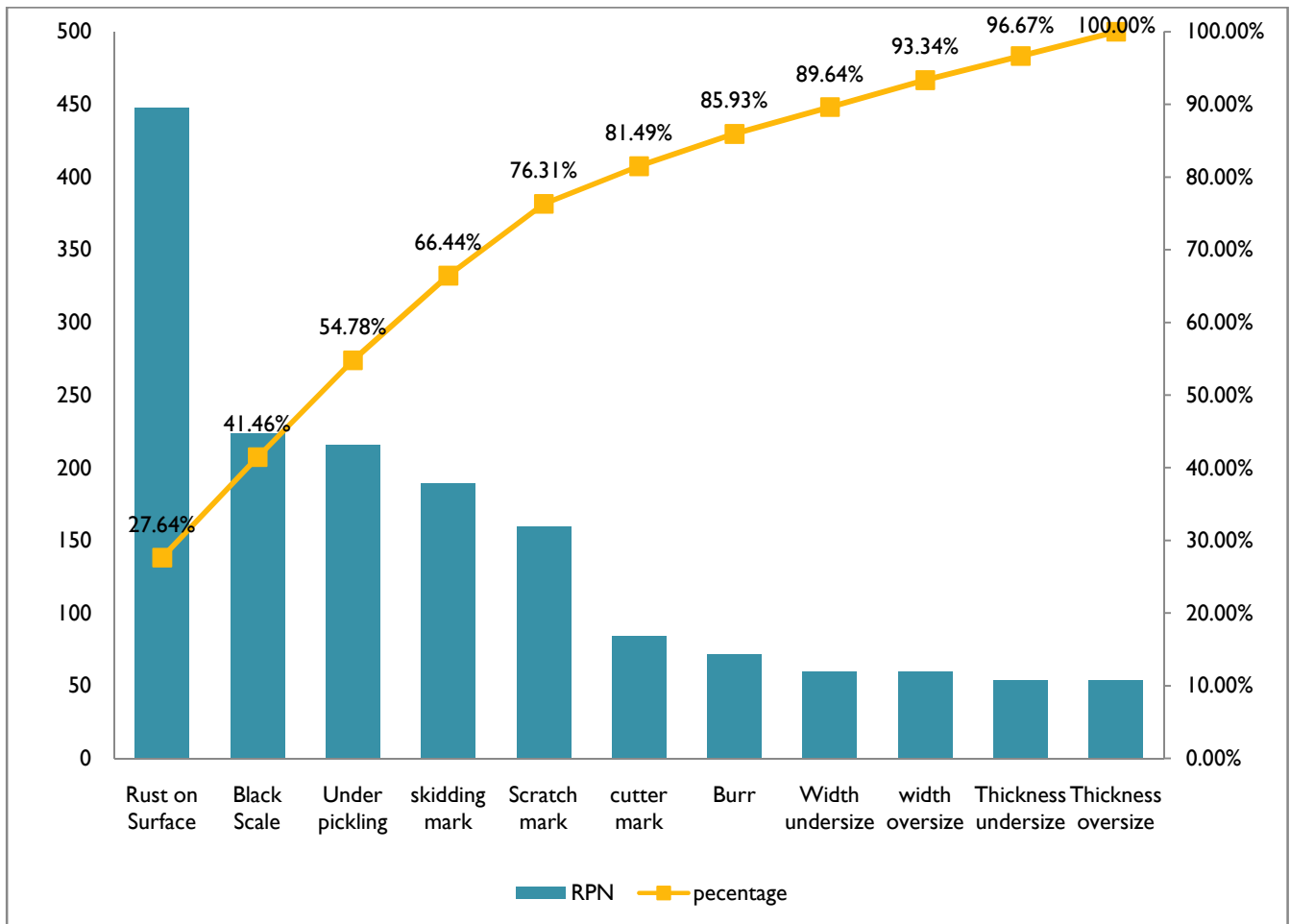
**TABLE 2: Severity and Detection PFMEA Custom Ranking, Customer Satisfaction Examples**

Severity rating		Detection evaluation criteria	Ranking
Effect	Severity Effect on Process	Example	
Hazardous without warning	may endanger operator (machine or assembly) without warning	No monitoring, measurement or sampling.	10
Hazardous with warning	may endanger operator (machine or assembly) with warning	Acceptable Quality Level (AQL) Sampling plan used for sampling Inspection.	9
Very High	100% of material may have to be scrapped, or rework time greater than two hours	100% visual Inspection.	8
High	Material may have to be sorted and a portion (less than 100%) scrapped,	100% visual Inspection with visual Standards.	7
Moderate	Material may have to be sorted and a portion (less than 100%) scrapped, and the rework time less than two hours	100% Manually Inspected using gauges.	6
low	Material may have to be reworked 100% on Process but does not go to customer end	Statistical Process control (SPC) Used in Process With Cpk 1.33 or higher	5
Very Low	Material may have to be reworked 100% with no scrap	SPC used in-Process with Cpk 1.67 or higher	4
minor	A portion of the production run may have to be reworked in process before it is processed	Does not apply.	3
Very minor	Slight inconvenience to process, operation or operator	Does not apply	2
None	No effect	Does not apply	1

**TABLE 3: Occurrence PFMEA custom Ranking**

Probability of Failure	Likely Failure Rates or Rework (Tons)	Rank
Very high: Persistent failures	$\geq 15$ Ton per month	10
	9 -10 Ton per month	9
High: Frequent failures	8-9Ton per month	8
	7-8 Ton per month	7
Moderate: Occasional failures	6-7 Ton per month	6
	5-6Ton per month	5
	4-5 Ton per month	4
Low: Relatively few failures	1.5-2 Ton per month	3
	1-1.5 Ton per month	2
	$\leq 1$ Ton per month	1

Failure Mode Identified and FMEA conducted for each failure mode to calculate the Risk Priority Number of respective Failure Mode. FMEA Identified the potential failure Modes, their causes and the Effects on the system for given Process. Based on the RPN calculation Rust on surface, Black Scale and Under pickling has maximum Risk when Compared to other failure.



**Fig. 2. Pareto Analysis of Failure Modes**

## 6. ROOT CAUSE IDENTIFICATION

Brain storming was conducted and the points were identified and added to the fish bone diagram.

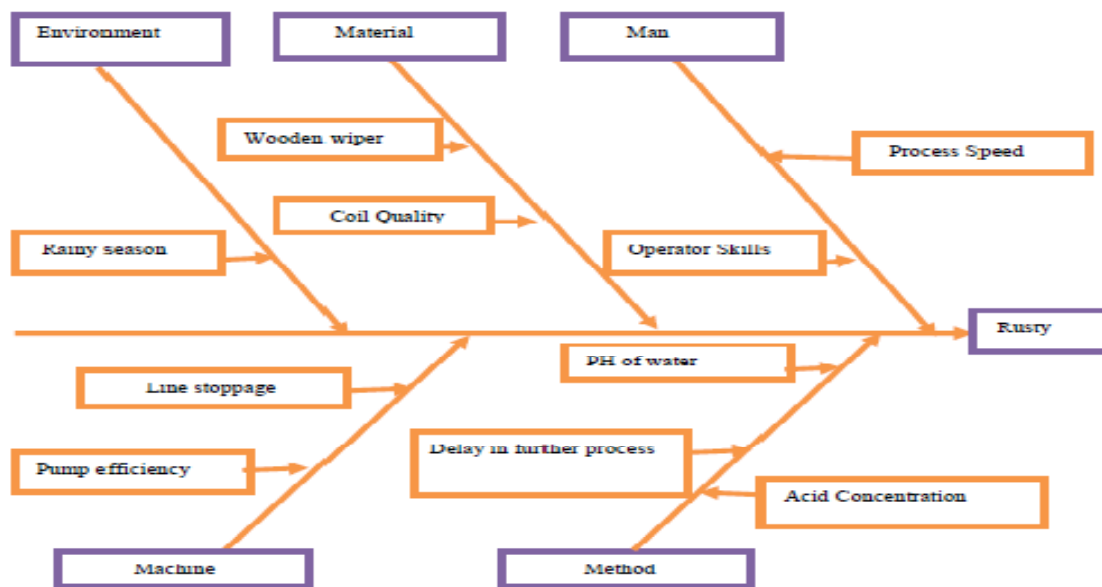


Fig. 3. Ishikawa Diagram for Rusty Patches on the coil after pickling process

## 7. RESULT AND DISCUSSION

Percentage Reduction in RPN

$$= \frac{\sum \text{Initial RPN} - \sum \text{Final RPN}}{\sum \text{RPN initial}} \times 100$$

$$= \frac{1657 - 930}{1657} \times 100$$

$$= 43.87\%$$

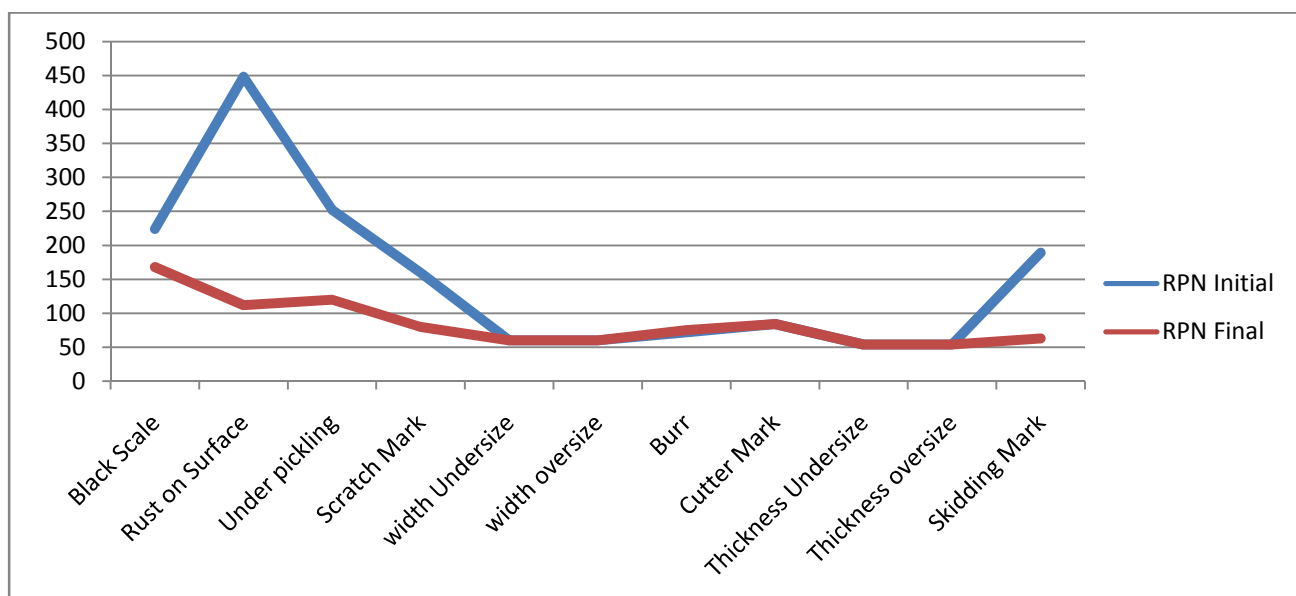


Fig. 4. Comparison Between Initial Vs Final RPN

**TABLE 4: FMEA Sheet**

Process Function	Potential Failure Mode	Potential Effects of Failure	S e v	Potential Cause / Mechanism of Failure	O c c u	Current Process Controls Prevention	Current Process Controls Detection	D e t e	R P N	Recommended Actions	Action Results				
											Action Taken	S e v	O c c	D e t	R P N
Pickling	Black scale on surface	Roll skidding during rolling process- Internal ppm	8	Low acid temp.	4	No specific control for low acid temperature	Visual check	7	224	maintain acid temperature within 42-48 deg.	temperature controller Installed	8	3	7	168
	Rust on surface	Customer Rejection	8	Acid and water not removed properly on strip	8	Wiper provided at acid tank exit	visual	7	448	Change Wiper	Replace wooden wiper with Rubber wiper	8	2	7	112
	Scratch Mark	Internal PPM	5	Foreign particle trapped in wiper	4	wiper change periodically	visual and inprocess inspection	8	160	wiper change daily	wiper changed	5	2	8	80
	Under Pickling	Customer Rejection	7	weak acid strength	4	No specific control for weak acid strength	check once per day with hydrometer	9	252	Temp & strength matrix to be developed and Implemented	Maintain acid strength range 10%-18%	5	3	8	120
HR slitting	width Undersize	Customer Rejection and internal PPM	5	Incorrect setting of cutter size	3	cutter size check by vernier scale	Trail piece check and inprocess Inspection	4	60						
	Width oversize	customer Rejection	5	Incorrect setting of cutter size	3	cutter size check by vernier scale	Trail piece check and inprocess Inspection	4	60						
	Burr	Internal PPM	5	cutting Allowances in cutter not proper and cutter Blunt	3	Inprocess inspection	visual	5	75						
	Cutter Mark	customer Rejection	4	incorrect cutter diameter selection, incorrect horizontal clearance	3	visual check and adjustment	visual	7	84						
Rolling	Thickness Under size	customer Rejection	6	Screw down adjustment on down side	3	Screw down scale given	Checking thickness manually(in process inspection)	3	54						
	Thickness Over size		6	Screw up adjustment on down side	3	Screw up scale given	Checking thickness manually(in process inspection)	3	54						
	Skidding Mark		7	Black scale remain on coil	3	Inprocess Visual check	Visual check on coil surface	9	189	black scale check at pickling line	temperature maintain in pickling process	7	1	9	63

## 8. CONCLUSIONS

Cause and Effect Diagram helped to think through causes of a problem thoroughly by pushing us to consider all possible causes of the problem, rather than just the ones that are most obvious.

FMEA analysis easily help in improving the efficiency of the manufacturing process and quality of the coil thus decreasing the number of defective and saving of rework cost and time. For each specific process the preventions suggested in the FMEA table can considerably decrease the loss to the manufacturing industry in terms of both money and time.

FMEA identified the potential failure modes, their causes, and the effects on the system for given process. Based on RPN calculation Rust on surface, Black scale, and under pickling had maximum risk when compared to other failure.

After performing process FMEA and action taken, the Risk Priority Number (RPN) reduce up to 43.87% and save process failure expected cost up to maximum 22, 200 Rs/ month or 2, 66, 400 Rs/ Year. That means 66.46% material Rejection/ Rework cost save after process FMEA.

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# Failure Mode and Effect Analysis of Annealing, Skin Pass Rolling and Slitting Processes for Cold Rolled Steel Coils

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**Abstract:** The success of any industry relies upon products that are as failure free as possible. The cost associated with defective products from liability or lost customer stand point can have unexpected impact on industry. In this paper, the quality problems raised in producing cold rolled annealed coils due to deficiencies in manufacturing process at an industry are addressed using Process FMEA technique. The processes considered for this analysis are annealing and finishing processes such as skin pass/temper rolling and slitting. The potential failure modes for each process are listed by brainstorming among team members and observing past rejection data. Then the Cause and effect of each failure are evaluated and noted in the FMEA sheet. The quantification of each failure is carried out by assigning rankings for the Severity (S), Occurrence (O) and Detection (D) of each the failure mode or its cause. The calculated Risk Priority Number (RPN) determines risk associated with these failure modes and corrective actions are determined for the failure modes having high RPN value in descending order up to the acceptable range of RPN. The fishbone diagram and Why-why analysis for prioritized failure modes determines corrective actions. After implementing these actions it is found that the quality is considerably improved and the loss to the industry in terms of both money and time is decreased.

**Keywords:** Cold Rolled Annealed, Process FMEA, Risk Priority Number, Slitting, skin pass rolling

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## 1. INTRODUCTION

Process FMEA is used to analyze the existing or new process and is driven by function of a process. It focuses on the risk of potential failure modes associated with the process safety, effectiveness, efficiency and problems with the functions of a product caused by the problems in the process.

Each manufacturing defect is a failure mode of a process, since the process should not produce it. Using Process FMEA an engineer can solve these failures occurred due to manufacturing process by deliberately controlling the cause of failure or limiting their bad effects

This paper includes application of process FMEA to a manufacturing industry producing Cold Rolled and Annealed coils to reduce rejection and reworks due to its quality problems. The processes considered for study is annealing and finishing processes such as skin pass/temper rolling and slitting. Process FMEA is applied systematically in step-by-step manner to minimize operational defects occurring during these processes. The potential failure modes for each process are listed by brainstorming among team members and observing past rejection data. Then the Cause and effect of each of failure are evaluated and noted in the FMEA sheet. The quantification of each failure is done by assigning rankings for the Severity (S) of the failure, the Occurrence (O) or frequency of the failure and

the Detection (D) i.e. probability of detecting the failure mode or its cause. The Risk Priority Number (RPN) is calculated by multiplying the assigned Severity, Occurrence and Detection ranking for each failure modes which determines risk associated with these failure modes. Once all Risk Priority Numbers are calculated for the considered failure modes, corrective actions are determined for the failure modes having high RPN value in descending order up to the acceptable range of RPN. The goal of a corrective action is to achieve suitable reduction in risk of the failure mode.

### 1.1 Objectives of Project Work

The main objective of our project work is make improvements in process to reduce rejection/reworks in the annealing, skin pass rolling and slitting operations using FMEA. To achieve this following sub-objectives are formulated.

- Address all potential failure modes in the processes
- Evaluate the effect of each failure mode
- Prioritize failure modes based on its RPN
- Suggest and implement necessary actions
- Verify the effectiveness of implemented actions.

## 2. LITERATUREREVIEW

The Failure mode and Effect Analysis was developed and implemented for the first time in 1949 by U.S. Army and later executed in Apollo space mission to moderate the risk. In 1950s the increasing attention given to safety and need to prevent predictable accidents in aerospace industry led to the development of FMEA methodology. Later it was introduced as key tool for increasing product quality and efficiency in manufacturing processes.

Arunachalam and Jegadheesan, 2006 presented a case study with reliability and cost based approach for the cooling system of passenger transport vehicles using data collected from state transport corporation depot. Teng et al., 2006 propose that the issues regarding reliability of a product must be included before the completion of design stage and one has to confirm that design requirements are met. Anette von Ahsen, 2008 implemented the cost-oriented FMEA to improve quality management. In order to suggest an improvement actions they included costs arising from faults detected by the customer, costs of faults detected within the boundaries of the company and costs associated with false positive inspection results in the evaluation of potential failures. Piyush et al., 2012 used FMEA methodology and implemented in a foundry for reducing rejections of bushes and to improve operational performance of the process. The problems identified in the various steps of core making process contributing for high rejection are studied and analyzed in terms of RPN to prioritize the attention for each of the problem. The criteria used to evaluate these problems or causes are the amount of damage caused to the production in terms of core rejection or lost production volume and subsequent monetary loss. Tejaskumar S. Parsana, et.al., 2014 has identified and eliminated current and potential problems from a manufacturing process of cylinder head in the company through the application of Failure Mode and Effects Analysis (FMEA) for improving the reliability of sub systems in order to ensure the quality which in turn enhances the bottom line of a manufacturing industry..

Puvanasvaran et.al., 2014 integrated the Poka Yoke concept to guide the action of engineers in the case of every potential failure that might be generated from the process input. S. B. Chikalthankar and G. S. Sawadadkar, 2015 used FMEA for process development and implement this tool in precision bearing manufacturing company. They integrated Statistical Process Control (SPC) for evaluating occurrences of failure in the needle cutting operation. Govind S. Dhage and S. B. Chikalthankar, 2016 addressed the limitations with the conventional FMEA approach. They tried to improve the representation of failures, and to evaluate these failures with consistent and meaning full risk evaluation criteria to facilitate cost based decisions. Banduka, N., et.al., 2016 proposed an integrated lean approach to Process Failure Mode and Effect Analysis

(PFMEA) for automotive industry for solving specific shortcomings. Some of those lean tools and principles integrated in PFMEA are: GenchiGenbutsu, Kaizen, standardized work, Jidoka and 5 why. This new PFMEA approach has proven to be very good and practical combination for identifying and fixing problems and failures.

## 3. BRIEF ABOUT THE INDUSTRY

Keshav Metals Pvt. Ltd. is a leading manufacturer of Cold Rolled Closed Annealed (CRCA) steel coils. The industry is situated at MIDC area, Waluj, Aurangabad, Maharashtra, India. Coils produced by Keshav Metals Pvt. Ltd are used in pipes & tubes industries, automobiles, rolling shutters, furniture, architectural utilities, and for specialized applications. The figure 1 shows the flowchart of the process at the industry. The input is pickled cold rolled coils which are annealed, skin passed and slit to required width and dispatched.

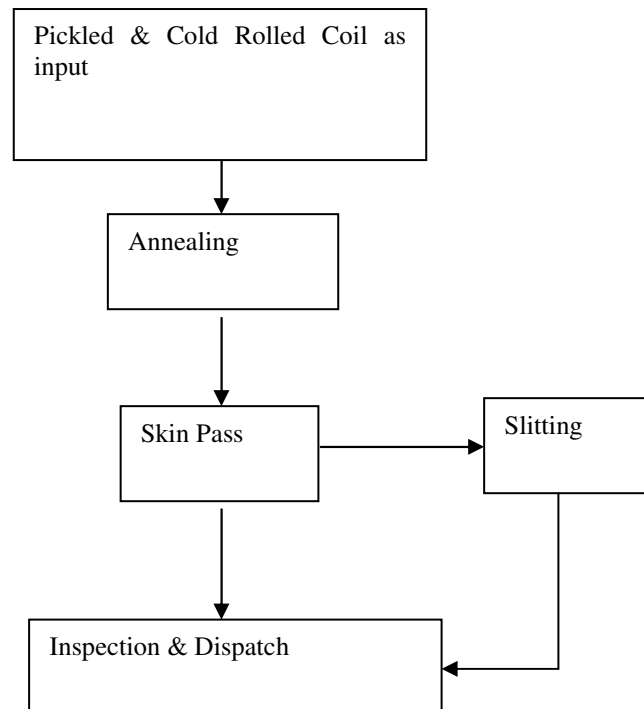


Fig. 1. Process flowchart at industry

## 4. METHODOLOGY

### 4.1 Brainstorming Potential Failure Modes

A potential failure mode represents the way in which the process could fail to perform its intended function leading to defective material. The failure modes of the product which could originate during processing are identified and listed as given in table 1 for each process by brainstorming and observing customer complaints and line rejection/rework records.

**TABLE 1: Brainstorming to find potential failure mode**

S N	Process	Potential Failure Modes
1	Annealing	High/low Hardness
		Black patches of coolant on surface
		Sticking of overlapping layers of coil
		Coil Buckling
2	Skin Pass / Temper Rolling	Thickness undersize/ oversize
		Thickness variation along rolling direction
		Thickness variation across width
		Roll marks, dents on strip Scratch marks
3	Slitting	Oversize/ undersize width
		Width variation throughout coil
		Burr on the edge
		Cutter Mark on surface
		Interrupted trimming
		Camber

#### 4.2 Ranking Criteria

The criteria used for ranking the severity, probability of occurrences and detection of failure modes are given in table 2 to 4.

**TABLE 2: Process FMEA severity evaluation criteria**

Rank	Effect	Criteria
10	Hazardous to operator	May endanger operator without warning
9		May endanger operator with warning
8	Major disruption	100% of product may have to be scrapped.
7	Significant disruption	100% of production run may have to be rework. (Major rework)
6	Moderate disruption	100% of production run may have to be rework. (Minor rework)
5		A portion of the production run may have to be scrapped
4		A portion of the production run may have to be reworked (Major rework)
3		A portion of the production run may have to be reworked.( Minor rework)
2	Minor disruption	Slight inconvenience to process, operation or operator
1	No effect	No effect on product

**TABLE 3: Process FMEA occurrence evaluation criteria**

Rank	Likelihood of Occurrences	Likely Failure Rates (Rework/months)
10	Very high (failure is almost inevitable)	$\geq 10$ Ton
9		8.1-10 Ton
8	High (repeated failures)	7.1-8 Ton
7		5.1-7 Ton
6	Moderate (occasional failures)	4.1-5 Ton
5		3.1-4 Ton
4		2.1-3 Ton
3	Low (relatively few failures)	1.5-2 Ton
2		1-1.5 Ton
1	No known occurrences on similar products or processes	$\leq 1$ Ton

## 5. PERFORMANCE ANALYSIS

Using these criteria, Risk Priority Number is calculated and value entered in FMEA sheet.

### 5.1 Prioritize the failure mode

The calculated RPN is be used to identify where the team should focus first for improvement. The higher the RPN, higher the relative risks. The table 5 below shows failure modes taken on priority for improvement.

**TABLE 4: Process FMEA detection evaluation criteria**

Rank	Likelihood of Detection	Criteria for evaluation
10	Almost Impossible	No current process control/ detect failure mode
9	Very Remote	Failure mode/cause is not likely to detect at any stage.
8	Remote	Failure mode detection in post-processing by operator-visual/audible/tactile means
7	Very Low	Failure mode detection post-processing by operator-using visual and variable gauging
6	Low	Failure mode detection post-processing by automated controls; stop process to prevent further defectives
5	Moderate	Failure mode/cause detection in-process by operator-visual/audible/tactile means only
4	Moderately High	Failure mode/cause detection in-process by operator-using variable gauging or automated controls
3	High	Failure mode/cause detection in-process by automated controls & automatically stop line
2	Very High	Failure mode/cause detection in-process by automated controls; prevent discrepant material from being made
1	Almost certain	Discrepant materials cannot be made because process has been error proofed

**TABLE 5: List of defects taken on priority**

S.N.	Type of defect	RPN
1	Width Variation during slitting	432
2	Black Patches on coil surface after annealing	252

#### 5.1.1 Width variation during slitting

The potential causes of width variation in slitting operation are brainstormed and summarized in fishbone diagram as shown in figure 2. From this the root cause for width variation is found as cutter/arbor deflection during operation and machine vibration. Therefore to eliminate problem of width variation due to arbor deflection during operation, the slitting setup is made more robust by providing horizontal beam as shown in fig 3(b) which acts as support to arbor holders during slitting operation. Figure 4 shows the run chart and figure 5 represents the histogram of width variation analysis before and after performing corrective action for slitting process. The histogram (b) shows that the variation in width during slitting operation is reduced and size is within the specification limits

#### 5.1.2 Black patches on coil surface after annealing

The fishbone diagram shown in figure 6 represents the potential causes that can leads to black colored coolant patches on coil surface after annealing. From this it is found that the residual coolant patches on surface of annealed strip is due to poor volatilization of rolling coolant and its burning on coil surface during annealing of tight coil in bell-type furnaces. This shows up as a carbon deposit on the strip surface in the form of black colored patches on the coil surface.

This problem of black colored patches on annealed coil surface is depends on how well the emulsions and other residues are removed during heating and purging stage of annealing and is therefore referred to the rolling conditions and the tension during coiling at the cold rolling mill.

Therefore it is advised to control the use of coolant and maintain lower coil tension during winding to get better surface cleanliness after annealing. Further this problem can

be prevented by providing coil winding tension indicator and controller at cold rolling mill stand.

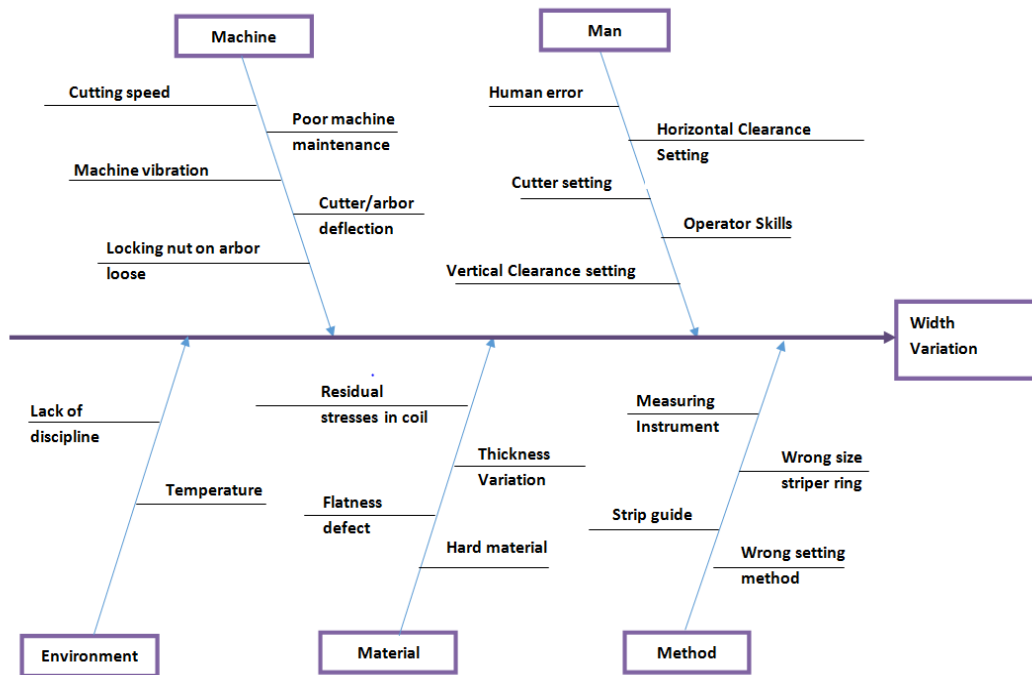


Fig. 2. Fishbone diagram for width variation in slitting operation

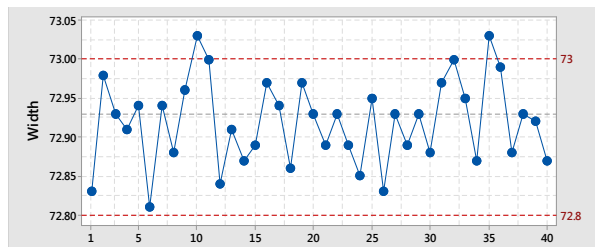


(a)

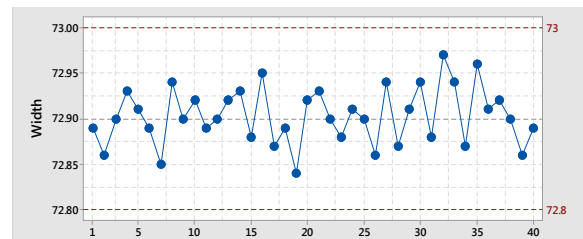


(b)

Fig. 3. Slitting process setup (a)before and (b) after corrective action



(a)



(b)

Fig. 4. Run chart for slitting (a) before and (b) after PFMEA

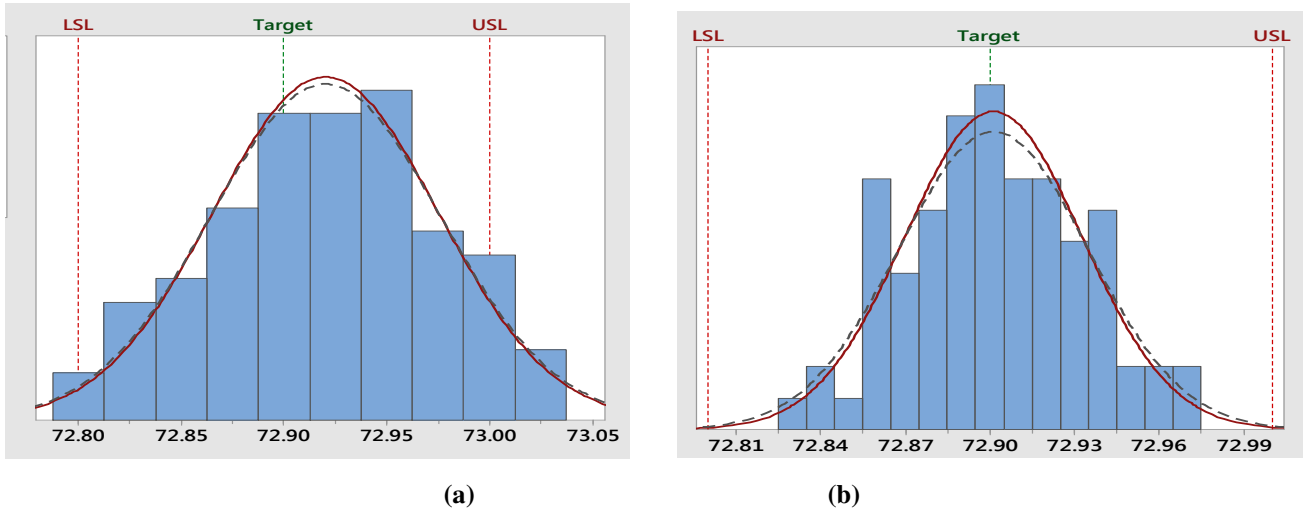


Fig. 5. Histogram of width variation analysis (a) before and (b) after corrective action

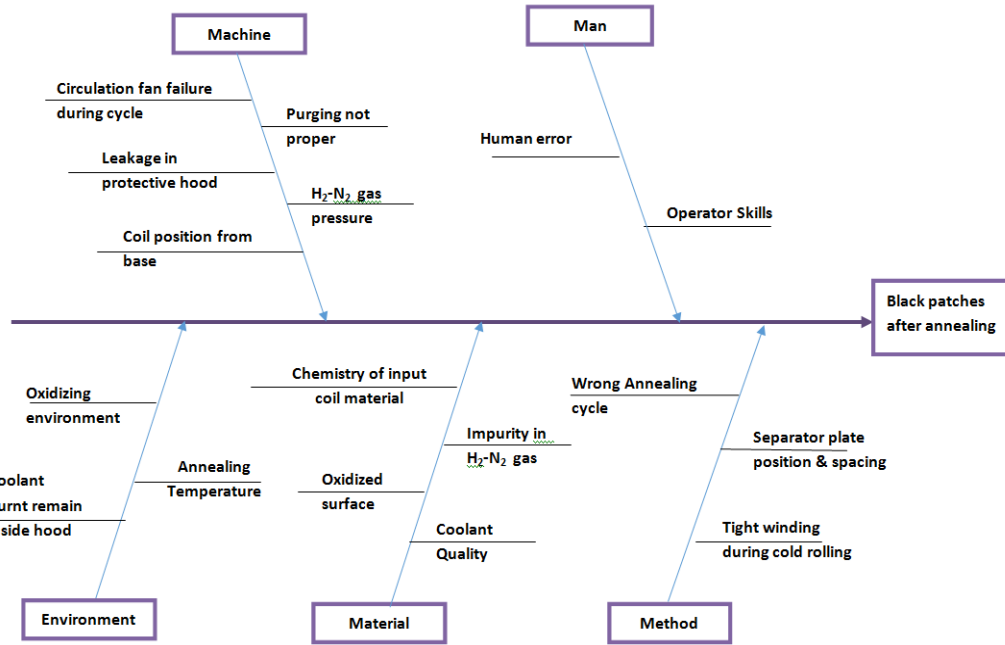


Fig. 6. Cause and effect diagram for black patches on coil after annealing

## 6. RESULTS

After implementing corrective actions, risk priority numbers are recalculated to see the impact of the improvement on process. The RPN after improvement are calculated and mention in the final FMEA sheet (table 6). Comparison of RPN's before and after corrective action is shown by line graph in figure 7.

### 6.1 Percentage Reduction in RPN

The reduction in RPN after performing recommended

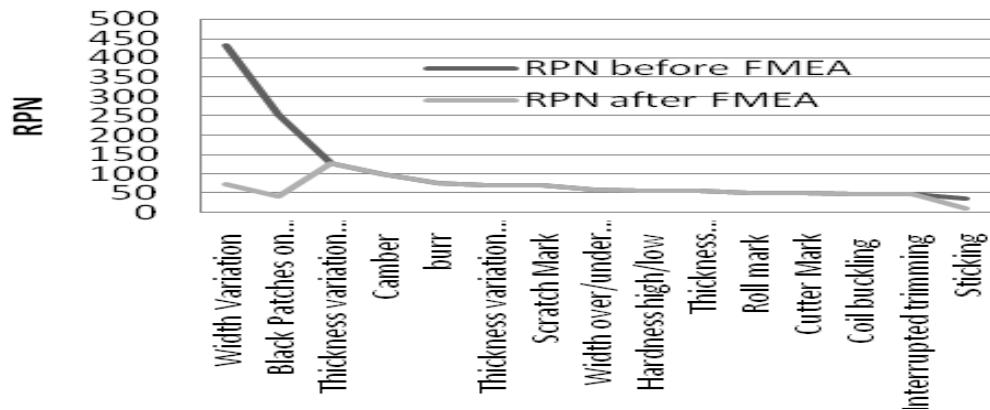
action represents the effectiveness of FMEA technique. It is calculated as Eq. 1

Percentage Reduction in

$$\text{RPN} = \frac{\sum \text{Initial RPN} - \sum \text{Final RPN}}{(\sum \text{RPN initial})} \times 100$$

$$= \frac{1527 - 933}{1527} \times 100 = 38.89\%$$

Therefore after performing FMEA about 38.9% risk of failure mode is reduced.



**Fig. 7. Comparison of RPN's before and after PFMEA**

**TABLE 6: Final Process FMEA Sheet**

Process & its Function	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Cause	Occurrence	Current Process Controls Prevention	Current Process Controls Detection	Detectability	RPN	Recommended Actions	Action Results				
											Action Taken	Severity	Occurrence	Detectability	RPN
Annealing : Anneal cold rolled coils to remove residual stresses	a. Hardness high/low	Customer Rejection	7	Annealing cycle not as per material properties	2	Annealing cycle defined according to material hardness and chemical properties	Hardness checking after annealing	4	56			7	2	4	56
	b. Black Patches on surface	Problem during coating at customer end	7	Contamination of surface by oil,dust, coolant/ Tight winding of coil	6	Black patches cleaned during temper rolling/skin pass rolling	Visual detection at temper mill stand	6	252	Lower the tension in coil during winding at cold rolling mill to allow to remove and vaporize coolant	Coil is loosely wound at last pass at cold rolling mill.	7	1	6	42
	c. Sticking	Sticky marks on surface	2	wrong selection of temp. cycle for annealing / Tight winding of coil	3	Annealing cycle defined according to material hardness and chemical properties & No specific value defined for tightness of coil	During skin pass	6	36			2	1	6	12
	d. Coil buckling	Coil shape change	4	Coils are not supported. Convector plates are not properly positioned	2	Defect removed in skin pass rolling due to tension	Visual	6	48			4	2	6	48
Skin Pass: Roll to finish thickness size and provide desired surface finish to surface	a. Thickness Over/under size	Customer rejection	7	Wrong roll gap setting	2	Scale provided for adjusting gap between rollers	Thickness measurement 3 times during rolling	4	56			7	2	4	56
	b. Thickness variation along rolling direction	Customer Rejection	7	Roller deflection, rolling speed variation, Deformed rollers	2	Roller inspection Included in Preventive maintenance	Thickness measurement 3 times during rolling (No continuous monitoring)	9	126	provide sensor for continuous monitoring of output thickness	X-bar R-charts drawn and Process capability found to check current machine condition	7	2	9	126
	c. Thickness variation across width	Customer Rejection	7	Roller axis not parallel	2	Two different scales for roll gap setting	Measure thickness at both edges and at center of strip	5	70			7	2	5	70
	d. Roll mark	Roller impression on coils.	5	Chatter/dresser marks on roll when grinding	2	Vial inspection	Trial pass after redressing of rollers	5	50			5	2	5	50
	e. Scratch Mark	Scratches on throughout the coil	7	Foreign particles entrapped in wiper	2	Clean wiper before stating skin pass rolling	Visual detection during process	5	70			7	2	5	70
CR Slitting: slit coil to required width	a. burr	Line Rejection	5	Horizontal and vertical clearance setting not proper	3	Standard clearance value provided to operator as per material thickness.	Visual detection at slitting output	5	75			5	3	5	75
	b Interrupted trimming	Line Rejection	6		2			4	48			6	2	4	48
	c. Width over/under size	Line Rejection/scrap generation	5	Cutter setting not correct	3	Paper shims are used to size adjustment	Measure width by digital vernier caliper	4	60			5	3	4	60
	d. Width Variation	Customer Rejection	8	cutter deflection/ arbor deflection/ machine condition	6	Three times inprocess width measurement	Visual	9	432	Minimize cutter deflection/machine vibration	Process capability index measured. Setup is made robust by reducing vibrations	8	1	9	72
	e. Camber	Strip not guided in die at customer end. Customer Rejection	7	Cutter clearance not uniform/ Defect in master coil	2	No any preventive measures. Camber if occurred then removed after slitting process	Camber measured after slitting	7	98			7	2	7	98
	f. Cutter Mark	Customer/line Rejection	5	Improper stripper ring selection/ Incorrect vertical clearance	2	stripper rings are selected based on size of cutter & Visual inspection and adjusting vertical clearance	Vertical Clearance setting by judgment and trial-error	5	50			5	2	5	50
Total									1527						933

## 7. CONCLUSIONS

This paper provides systematic approach for the estimation, analysis, and evaluation of risks. This process FMEA document can be helpful for future use and continuous process improvement in the industry.

The implementation of process Failure mode and Effect Analysis in CRCA strip manufacturing industry gives following outcomes

- Based on RPN calculation width variation in slitting operation and black colored coolant patches had maximum risk when compared to other failure.
- Implemented action decreases occurrence of defective material production in the slitting operation by providing horizontal support to the vertical arbor holders which acts as a beam restricting cutter and arbor deflection during slitting and make the process more robust.
- Statistical Process control (SPC) gives the estimation of variation in the output width of coil during slitting operation.
- The residual coolant which remains on strip surface gets evaporated during heating, on keeping low tension during winding at cold rolling mill. Therefore quality and cleanliness of coils after annealing process is improved.
- After implementing recommended action in Process FMEA about 38.9% reduction in Risk Priority Number (RPN) is observed.

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# Study of Influence of Deep Cryogenic Treatment on Hardness and Microstructure of Various Carbon Contain Materials: A Review

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**Abstract:** The objective of this paper is to understand the effects of cryogenic treatment particularly on hardness and microstructure of various carbon contain different materials like ferrous alloys, different steels etc. This article provides a review on the research work of cryogenic treatment process. Study shows that different results in terms of improvement in hardness and microstructure which are mainly depends on carbon percentage, austenizing temperature, soaking time and tempering temperature.

**Keywords:** Cryogenic treatment, Austenizing temperature, Microstructure, Phase Transformation, Hardness, soaking time.

## 1. INTRODUCTION

The importance of deep cryogenic treatment process is increases from last few decades in the application of carbon contain alloys, Cryo process is considered as add-on process over the conventional heat treatment process. Cryogenic processing is a sub-zero heat treatment that affects the entire cross-section of materials and components, with the objective of improving mechanical properties such as hardness, wear resistance, by causing micro structural changes into different stable or meta- stable states.[R. Thornton et al., 2013] In cryogenic treatment process liquid nitrogen (LN₂) is generally used as cryo-fluid for treatment of material.

Three sub-zero treatments can be categories according to temperature as:

1. Cold treatment (273–193K),
2. Shallow cryogenic treatment (193–113K)
3. Deep cryogenic treatment (113–77K) which is invariably referred to as DCT [R. Thornton et al., 2013].

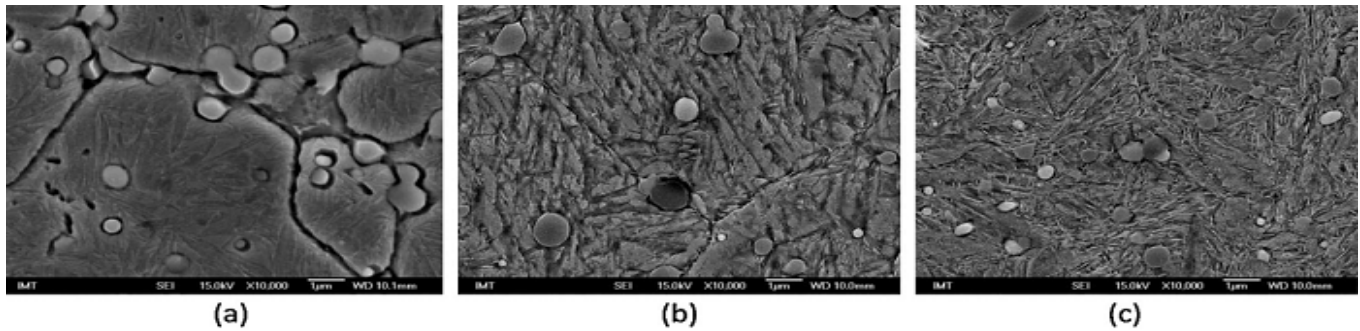
In this process transforms the retained austenite into martensite and causes the precipitation of finely dispersed carbides [1]. In first stage substance is cooled down up to -130 °C, retained austenite is transformed into martensite as that occur in conventional sub-zero heat treatment process. In second stage of substance is cooled up to -196°C, in this process primary martensite decomposed through a time-dependent transformation.[ R. Thornton et al., 2013], Deep cryogenic treatment makes the retained austenite vanish.[ A Akhbarizadeh et al., 2009]

## 2. LITERATURE REVIEW

B. Podgornik et al., 2016 studied the effect of DTC on different tool steel material and it is found that material having low carbon contain and higher W and Co contain cold-work tool steel (A1) shows great improvement in fracture toughness and and at the same time maintains the high hardness. From another sample (A2) with higher C contain DCT shows the negative effects in hardness, and high speed steel (B1) shows almost no effects on its property.

**TABLE 1: Nominal chemical composition of tool steels used in the investigation (in wt %) [3]**

Material	C	Si	Mn	Cr	Mo	V	W	Co
A1	0.85%	0.55%	0.40%	4.35%	2.80%	2.10%	2.55%	4.50%
A2	2.45%	0.55%	0.40%	420%	3.80%	9.00%	1.00%	2.00%
A3	1.65%	0.60%	0.30%	4.80%	2.00%	4.80%	10.40%	8.00%

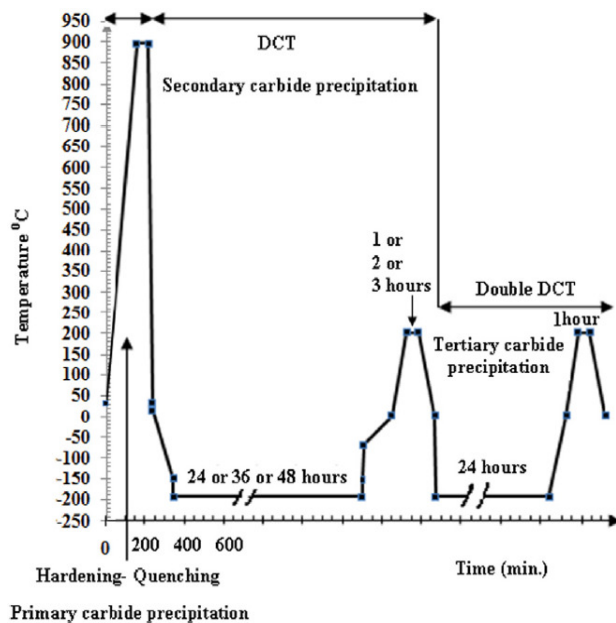


**Fig. 1. Microstructure of low carbon contain cold work tool steel (A1) after (a) quenching, (b) conventional triple tempering and (c) DCT and single tempering [3]**

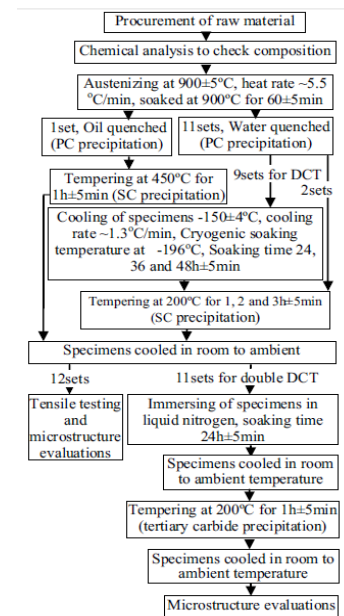
Talking about microstructural change it is found that low carbon contain tool steel can be related to formation of finer needles like martensite and martensitic transformation accompanied by plastic deformation of primary martensite. While for high carbon contain cold work steel high volume fraction of more stable MC carbides which may change precipitation kinetics lead to properties impairment after DCT.

Seyed Ebrahim et al., 2013 Studied the effect of DCT on 45WCrV7 material. 45WCrV7 is mostly used for cutting

blades and punching tools manufacturing. In this research they have taken different soaking and tempering times for analysis purpose to improve mechanical property and microstructure of material. From study it was observe that maximum toughness could be obtained by increasing soaking and tempering times. Toughness is improved due to pullout of high population density of SCs occurs. Hardness can be effectively increased by increasing soaking or tempering times, but leads to increase in production time results in high cost. So to reduce production time and cost increase in tempering time is fesibke alternative.



**(a)**



**(b)**

**Fig. 2. DCT and double DCT (a) cycles and (b) flow chart for experimental procedure [4]**

Precipitation of the SC was primarily due to the expansion resulting from transformation of the retained austenite into martensite. It is also observed that for the tool steel, double DCT had almost no effect on significance effect on microstructure of 45WCrV7.

Chen-hui et al., 2015, studied the Effects of deep cryogenic treatment on microstructure and properties of WC-11Co cemented carbides with various carbon contents

**TABLE 2: Properties of WC–11Co with various carbon contents before and after deep cryogenic treatment [5]**

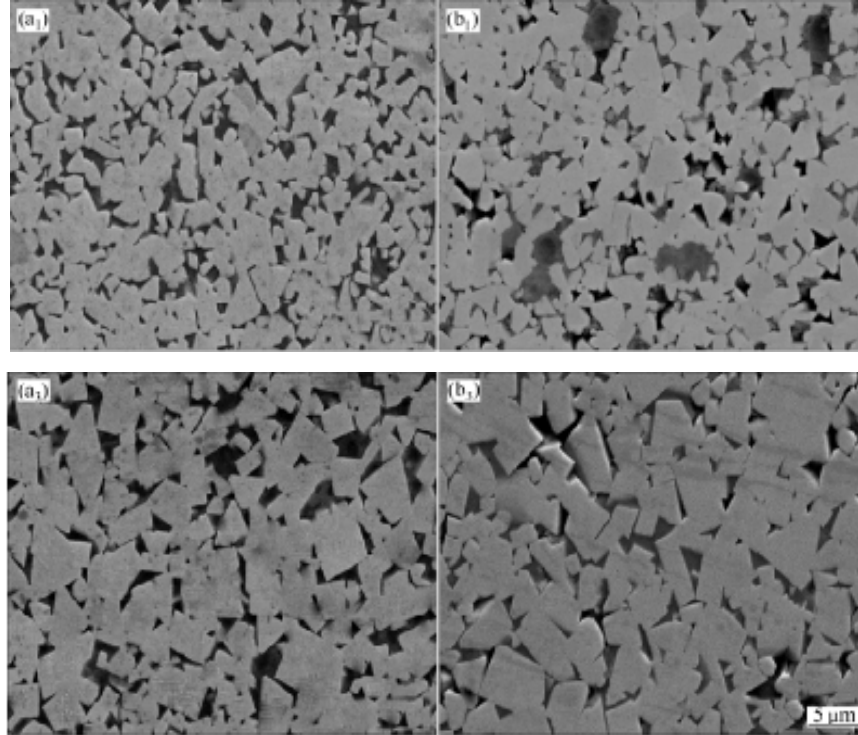
Sample	Mass fraction of Carbon %	Composition	Hardness
UT1	4.45	WC+Co+Co ₃ W ₃ C	87.9
UT 2	4.92	WC+Co	87.15
UT3	5.25	WC+Co+Graphite	87.01
DCT 1	4.45	WC+Co+Co ₃ W ₃ C	88.25
DCT 2	4.92	WC+Co	87.20
DTC 3	5.25	WC+Co+Graphite	87.25

In this study they have taken three different samples with various carbon percentage and composition. In table 2 UT stands for untreated sample and DCT stands for deep cryogenically treated sample. From study it was found that the hardness values in the deep cryogenically-treated sample were increased by 0.39%, 0.06% and 0.28%, respectively.

According to researcher it depends on two factors one is attributed to the compressive residual stress, which is induced by the large difference of thermal expansion coefficient between WC and Co phases during the DCT progress, second is densification of Co phase has an

important effect on the hardness of samples. Deep cryogenic treatment enhances the hardness and bending strength of the alloys.

Talking about microstructure it was observed in Figure 2 that microstructures of the sample with various carbon contents before and after deep cryogenic treatment. In the low carbon alloys, it can be observed that from Figures. 2(a1) and 2(b1) that  $\eta$ -phase is more in cryo treated sample, which are induced by martensite phase transformation in the DCT. In the carbon-rich alloys, as shown in Figures. 2(a3) and (b3), free carbon is formed while the  $\eta$ -phase disappears in the sample.



**Fig. 2. SEM images of WC–11Co cemented carbides with low and high carbon contents before and after deep cryogenic treatment: (a1) low carbon alloy UT-1; (b1) low carbon alloy DCT-1; (a3) rich carbon alloy UT-3; (b3) rich carbon alloy DCT-3[5]**

After studying microstructure it was found that WC grains are refined into triangular prism with sound edges via the process of spheroidization, but WC grain size has no evident change compared with that of untreated alloys.

M. El Mehtedi et al., 2012 done the Analysis of the effect of Deep Cryogenic Treatment on the hardness and microstructure of bX30 CrMoN 15 1 steel, in this research they found that the microstructure of the WQ material austenized at 1200 °C; the structure is partly martensitic, with a substantial fraction of retained austenite. The microstructure of the steel austenized at 1200 °C, after cooling in air (AC condition) did not show any significant difference. Deep Cryogenic treatment results in the almost complete transformation of the retained austenite, and also appears to affect the precipitation sequence. The maximum peak hardness is obtained after tempering the DCT samples at 450–500 °C. A simple model, which takes into account the single contributions of martensite, retained austenite and carbides carbonitrides, was able to describe the variation in hardness as a function of austenizing temperature.

Yang Gao et al., 2016 studied the effects of deep cryogenic treatment on the microstructure and properties of WC-Fe-Ni cemented carbides, Sample is deep cryogenically treated for around -196°C for three different cryogenic treatment time 2 hrs, 12 hrs, 24 hrs. from study it is found that as deep cryogenic time increases the martensitic phase transform from  $\alpha$ -(Fe, Ni) has taken place. The  $\gamma \rightarrow \alpha$ -(Fe, Ni) phase content in the binder phase gradually increases from 12.7% to 86.8% (wt.%) and W particles precipitate from the binder phase and hardness improved around 20%. The change of the properties can be primarily attributed to the fact that the martensite phase transformation from  $\gamma$ -(Fe, Ni) to  $\alpha$ -(Fe, Ni) and precipitation of W particles in the binder phase improve the hardness and strengthen the binder phase during the deep cryogenic treatment.

### 3. CONCLUSION

Cryogenic treatment process is considered as add-on process over the conventional heat treatment process. The results of this broad review on the effects of cryogenic treatment on hardness and microstructure indicates that

1. Deep cryogenic treatment enhances the hardness considerably than the other conventional heat treatment process,

2. Increased in hardness is significantly high in case of low carbon contain material compare to higher carbon contain.
3. Improvement in hardness is observed due to transformation of retained austenite into martensite at microstructural level.
4. Amount of hardness improvement is also depends on various parameters like soaking time, rate of heat, austenizing temperature, soaking temperature, grain size, tempering time, tempering temperatures etc.

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# Modeling, Analysis & Simulation of Micro Resistance Butt Welding Setup

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**Abstract:** This paper aims to provide a robust and flexible design of micro resistance butt welding setup. Resistance butt welding has been extensively used for joining two metal pieces. This paper gives an insight about the analysis and simulation of resistance butt welding process including their implications and limitations. A detailed simulation of the entire resistance welding process which includes analysis of thermo physical properties, thermal conductivity, coefficient of thermal expansion, electrical resistance, specific heat, tensile strength, etc. have been done. For numerical simulation & analysis of welding process parameters, two low-carbon steel work pieces have been taken in a symmetric butt welding model and an electro-thermal finite element method has been developed. The simulation results reveal that the maximum weld zone diameter occurs at the end of the heating stage which is an irreversible phenomenon. Resistance butt welding confers permanently leak proof surface. Besides proposing a versatile setup, this paper fulfills an identified need to do an overall modeling and analysis of resistance butt welding setup.

**Keywords:** Resistance butt welding, resistance welding, modeling, analysis, micro setup.

## 1. INTRODUCTION

In today's era, welding has found its boundless use. General day to day use items, e.g., automobile cars, aircrafts, ships, electronic equipment, machinery, household appliances, etc., depend upon welding. Welding is applied in vast areas due to its advantages like, easy to be done, can be made as strong as parent metal, economical, fast in nature, etc. Today, welding had taken over riveting and other fastening processes. Earlier bridges, ships and boilers were riveted, are now welded. Welding can produce a 100% efficient joint which is difficult to make by riveting [Khanna, 2009]. There are 35 different welding processes. This paper focus on Resistant butt welding analysis only. Compared to typical fusion welding processes, the RBW process has advantages such as speed, ease of control, fewer defects, enhanced weld properties, simplicity of equipment and the ability to join difficult-to-weld materials. These qualities make RBW an appropriate welding process to be utilized in various industrial settings; such as assembling automotive bodies, sealing of containers of high-level nuclear waste, joining steel materials, super alloy materials, aluminum alloys and parts made of dissimilar materials [8]. Kanne expressed that in comparison with fusion welding processes, the chemical composition and metallurgical properties are not significantly changed leading to better mechanical properties. Simplicity, welding speed, capability of remote control and independence of welding quality from the operator skill are the other advantages of this process [Kanne Jr, 1994]. He pointed out that advantages of RBW, compared to fusion welding processes, include fewer defects and stronger welds with a faster and

more reliable process [Kanne Jr, 1994]. Resistance welding didn't require fluxes shielding gasses or filler materials, so metallurgy of the weld depends only upon parent material. At present time, welding practice is divided into about 70% Arc welding with balance between Resistance welding and Oxyacetylene welding [Khanna, 2009].

In this study evaluation of RBW and its different parameters is investigated theoretically. This paper also aims to give a robust and flexible design of micro setup of resistance butt welding, which can also be used for seam welding with some minor changes.

## 2. AFFECTING PARAMETERS

There are four parameters that affect the RBW process:

- **Resistance:** This is responsible for generation of heat in the process. But in the RBW process there are three resistance working simultaneously. First Resistance at the contact of electrode and workpiece ( $R_1$ ), second is the resistance of workpiece to the flow of current ( $R_2$ ) and third one is the resistance at the faying surface ( $R_3$ ). Here,  $R_1, R_2 \ll R_3$ .

So, contact resistance depends upon current and upset pressure. Rudzitis et al. (1998) gives an equation to relate contact resistance and applied pressure  $P$ .

$$R_c = \frac{k_r \rho E^2}{[P 2a_1(1 - \nu^2)]^2} \left( \frac{R_a}{s_{m1}} \right)$$

Where  $a_1$  is the contact radius of the electrodes in spot welding,  $\rho$  is the resistivity of the material,  $k_r$  is the

surface anisotropy coefficient,  $R_a$  is the surface roughness,  $S_{ml}$  is the spacing parameter between surface peaks,  $E$  is the Young's modulus and  $\nu$  is the Poisson's ratio. So, from above equation it is visible that  $R_c$  is inversely proportional to applied pressure.

- **Current:** - As per joule's law, heat energy generated depends upon square of current applied. So, current is another important factor. The step-down transformer is used for current. While other parameters are constant, the temperature is regulated by controlling the magnitude of current.. The current used in the welding process is optimized. Mohsen et al., (2010) showed that with increasing the electrical current in the heating stage, mechanical strength of the joint increases to a specific limit and then decreases with a mild gradient, Fig2. Actually, excessive increase in the current causes melting of the mating surfaces and so the gradual drop in the mechanical strength [Sharifitabar et. al, 2011].

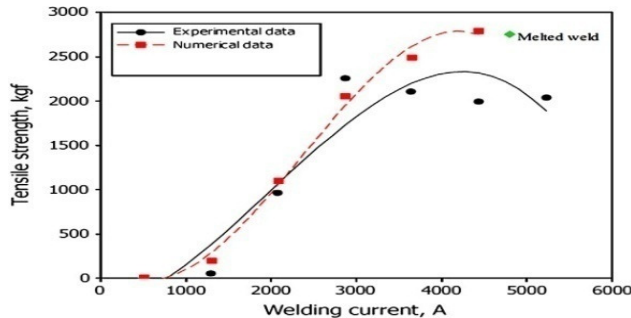


Fig. 2. Effect of variation of electrical current in heating stage on tensile strength.

- **Pressure:** - Pressure permits the weld to be made at lower temperature. It also provides a forging action and thus reduces weld porosity. Little electrode force can lead to surface burning and pitting of the electrodes. On the other hand, too high electrode force decrease the contact resistance thus resulting in decreased total heat generated at faying surfaces. Sharifitabar et al., (2011) shows that with increasing of the upset pressure, strength of the joint increases firstly and then decreases, shown in Fig 3.

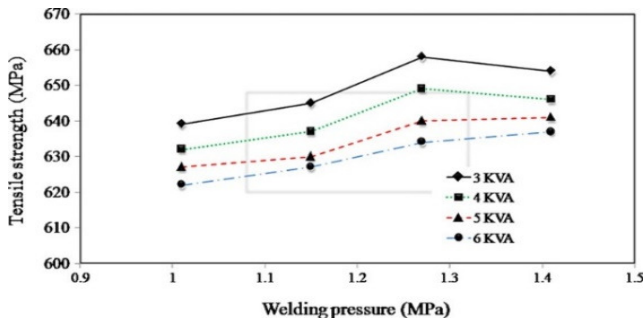


Fig.3. Effect of upset pressure on tensile strength of the joint.

- **Time:** - It is also referred to as cycle time. It consists of four stages: -

- Squeeze time:* - It is the time between the initial application of the electrode pressure on the workpiece and the initial application of current to make the weld.
- Weld time:* - During this period welding current flows through circuit.

Mohsen et al., (2010) also shows the variation of tensile strength verses time of heating or welding. It reveals that maximum tensile strength increases with a mild gradient until the time reaches a specific value [Sharifitabar et al., 2011], shown in fig 4.

- Hold time:* - It is the time during which force act at the point of welding after the last impulse of welding current ceases.

The effect of post-weld heating time on the tensile strength is shown in Fig 5 [Sharifitabar et al., 2011].

- Off time:* - It is the interval from the end of the hold time to the beginning of the squeeze time for the next welding cycle.

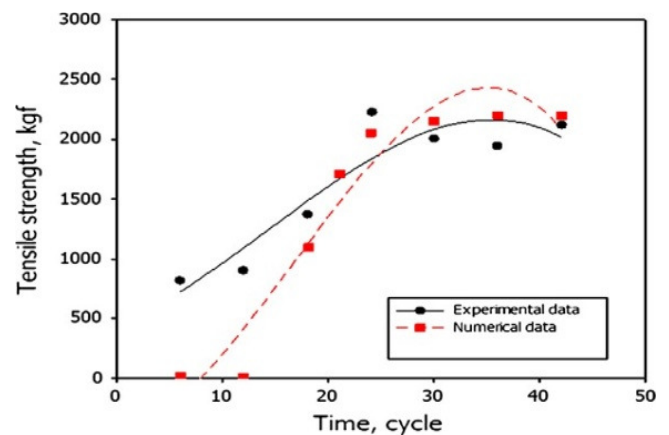


Fig. 4. Effect of variation of heating Time on tensile strength

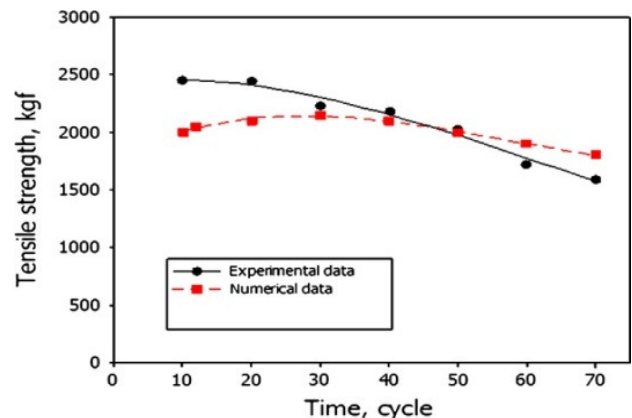


Fig. 5. Effect of variation of post weld time on tensile strength



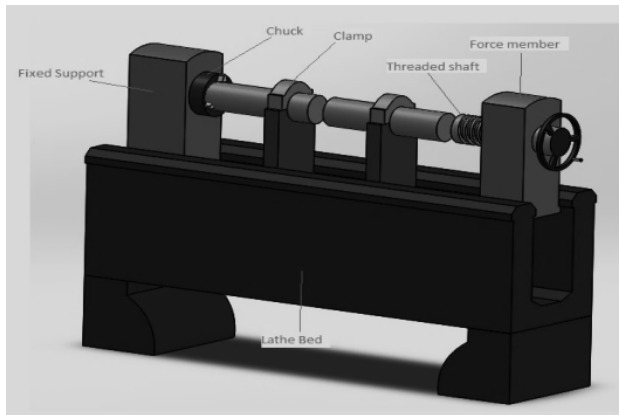


Fig. 6. A simple resistance spot welding cycle

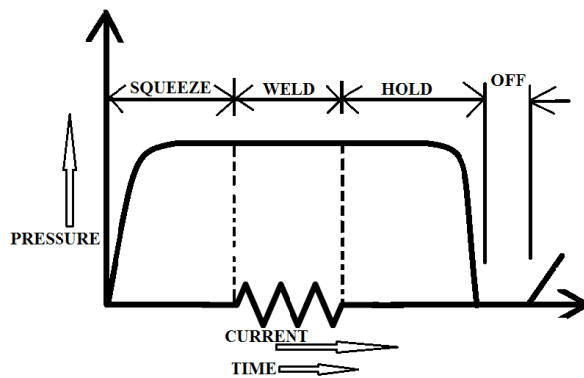
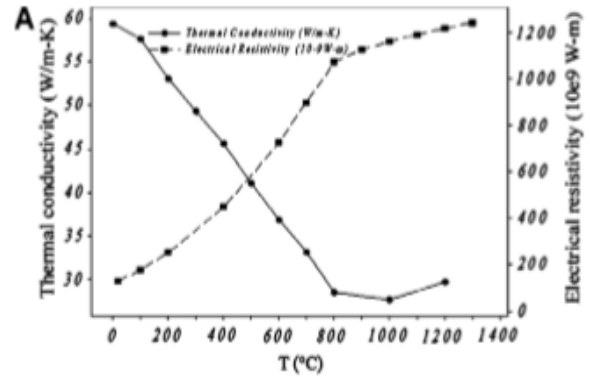
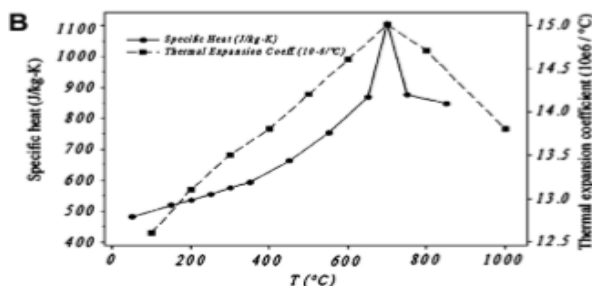


Fig. 7. Micro setup of RBW

### 3. MATERIAL AND WELDING CONDITION

Both the rods used are of low carbon steel so their micro structures comprises of pearlite and ferrite phases. Material properties are employed in their electrical-thermal-mechanical model as presented below. In order to increase the accuracy, thermo physical properties, including thermal conductivity, coefficient of thermal expansion, electrical resistance, specific heat, density, elasticity of yield stress and Poisson's ratio are assumed to be temperature dependent. For the second stage simulation and testing of the tensile strength, the ultimate strength of the low carbon steel was chosen to be 400MPA. From the simulation results drawn, the results inferred has been depicted below in the form of graph.



### 4. NUMERICAL RESULTS AND SIMULATION

In order to exemplify the heat generated in the contact faying surfaces under different phases, the simulation process was carried out. The figure below shows the temperature distribution in the weldment at three different times during the whole welding process. In the beginning it was observed that the temperature at the center of the faying surface increased very fast. As shown in the figure 7, the temperature is maximum after 12th cycles at a position away from the center line along the faying surfaces. Here, the heat generated along the contact line of the of the faying surfaces is due the contact resistance. It is inferred that on reaching then first half of the 14th cycle, the temperature level exceeded 350°C. From figure 8, it is clear that at the end of the heating time, i.e, 24th cycle, the temperature of the faying surfaces reaches to 765°C. This stage shows the joint point of low carbon steel which shows that the weld zone starts at this temperature level. Figure 9 shows the typical temperature distribution in the weldment at the end of the post weld heating time. While examining the work pieces interface, the maximum temperature is found at the central region which further drops to a lower value at the periphery. Figure 10 shows the temperature changing histories at three different locations. The computed results indicate that there was a difference in the temperature scale during welding. The peak temperature is observed at the center typically at the end of the heating time ( 24th cycle). After this there is no significant increase in the heating rate during the post weld heating time and the post weld heating current. Consequently there was no further increase in the weld zone size during the post weld heating time and the post weld heating current. From figure 10, it can be easily inferred that the maximum temperature of point 1 is about 1080°C. The nodes temperature decreases slowly during the post welding heating stage and its maximum temperature reaches to 680°C at the post welding heating stage. From this result, it can be revealed that the size of the simulated weldment at the end of the post heating stage is smaller than be at the heating stage. With the examination of the thermal history, it can also be inferred that the maximum weld zone diameter occurs at the

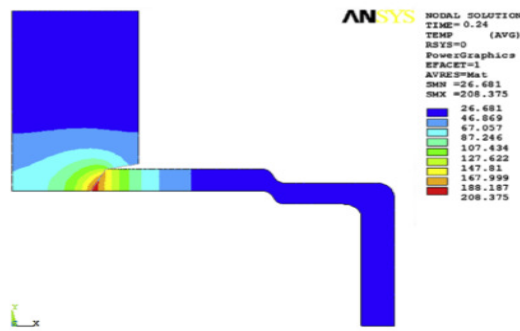


Fig. 7. Temperature distribution at 12th cycles of welding process.

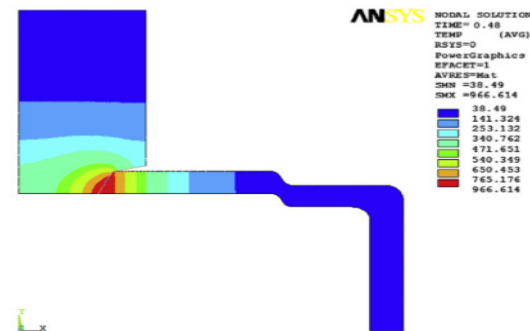


Fig. 8. Temperature distribution at 24th cycles of welding process.

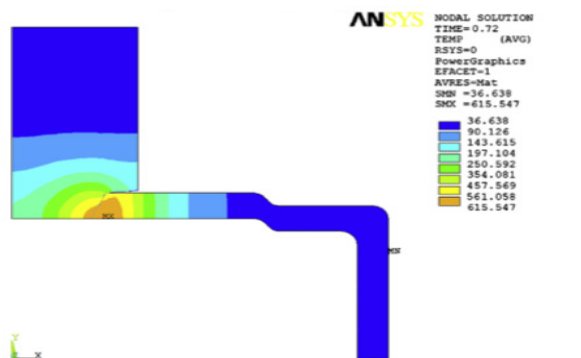


Fig. 9. Temperature distribution at 12th cycles of post-weld heating process.

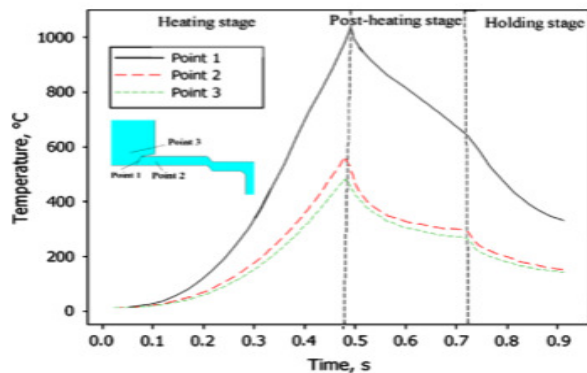


Fig. 10. Temperature histories at three location in UW process.

end of the heating stage which is an irreversible phenomenon. These simulation results demonstrate that the magnitude of the post heating current and the post weld heating time should be selected after careful examination of mechanical and metallurgical properties of the weldment.

## 5. RESULT & CONCLUSION

In this paper, modeling and analysis of micro RBW setup was carried out. It is found that RBW has many advantages over other welding processes. It can be used for large varieties of metals and alloys like stainless steels (including A-286), super alloys (including TD nickel), refracting metals (including tungsten) and aluminum alloys (including 2024).

The paper also gives a deep analysis of various affecting parameters of RBW, and how they can be controlled to give a good weld. The design of micro RBW setup was also proposed which is robust and flexible in nature. Besides, the simulation of the entire welding process was also carried out and various graphical proven results were found out. This design could also be used for seam welding process with some minor attachments and changes.

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# Lean Six Sigma Implementation Barriers: An Integrated Approach of ISM and Fuzzy MICMAC

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**Abstract:** The aim of this paper is to identify Lean Six Sigma barriers (LSSBs) to inspect interrelationships among these barriers and classify these barriers into driving power and dependence power using an integrated interpretive structural modeling (ISM) and fuzzy Matriced Impacts Croisés Multiplication Appliquée à un Classement (MICMAC) methodology. While the ISM methodology analyses the interactions among the LSSBs, fuzzy MICMAC analysis is employed to obtain insights into the dependencies among the LSSBs. A total of ten LSSBs were identified through the literature review. The research shows LSSBs having high driving power and low dependence have strategic importance because of their driving nature, while the LSSBs having high dependence and low driving power are more performance orientated. Therefore, it is the responsibility of LSS executives to address the high driving power LSSBs for the enhancement of LSS performance. This categorization provides a useful tool to top management to differentiate between independent and dependent LSSBs.

**Keywords:** Lean Six Sigma, LSS, ISM, Fuzzy MICMAC

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## 1. INTRODUCTION

Lean is about mastering the resources in accordance with the customer's needs and to reduce needless waste. The Lean concept was presented on a bigger scale by Toyota in 1950, but not branded lean manufacturing until the now famous book about the automobile appeared in 1990 (Womack, Jones, & Roos, 1990). Lean principles are fundamentally customer value driven, which makes them suitable for many manufacturing and distribution sites (Näslund, 2008; Snee & Hoerl, 2007). Motorola was the first company to instigate a Six Sigma method in the mid-1980s (Nave, 2002). Six Sigma is a business operation that allows companies to significantly advance their outcome by designing and monitoring daily business needs in ways that diminish waste and resources while escalating customer satisfaction. The Lean Six Sigma (LSS) concept can help organizations to enhance the operational efficiency, by uniting the benefit of lean and Six Sigma (Michael, Rowlands, & Kastle, 2004; Snee, 2010). While lean does not acquire the tools to lessen disparity and offer statistical control and Six Sigma does not endeavour to build up a linkage between quality and speed, the purpose of the combined tool LSS provides the valuable solution to increase efficiency and better quality in the industries. The benefits of combining lean and Six Sigma are modernize process stream to decrease complexity, reduce downtime, condense cycle period and lessen waste, get better product quality, attain constancy in product delivery, condense process and product expenses, reduce process disparity to reduce waste such as the waste of defective products, improve process control to maintain stable and expected processes (Antony, Kumar, & Madu, 2005; Antony,

Setijono, & Dahlgaard, 2016; De Koning, Does, & Bisgaard, 2008; Näslund, 2008).

However, regardless of these significant advantages, organizations keep on encountering an obstruction which ruins them from effective LSS implementing. These barriers/ obstruction are known as LSSBs. They exist inside (intra-firm) and outside the organization (inter-firm). Many studies focus on identification of these LSS barriers. Organization need to overcome these barriers hence can effectively implement LSS without many efforts. But only identification of these LSSBs is not enough, identification of the interrelationship among various LSSBs and identify the most driving barriers is requires for successful LSS implementation because these barriers are not only effect the LSS implementation but also effects on one- another. So in this study to obtain the interrelationship among identified LSSBs the interpretive structural modelling (ISM) and to clusters these LSSBs accordance to drive- dependency relationship fuzzy MICMAC (Matrix of Cross-Impact Multiplications Applied to Classification) analysis has use.

The structure of this study is as: In section 2 the details of literature review is provided. The application of combine ISM+MICMAC analysis is presented in Section 3. Finally the discussion and concluding remarks are presented in Section 4 and Section 5.

## 2. LITERATURE REVIEW

From vast LSS literature, initially we have identified total twenty-three LSS implementation barriers; we include opinions of industry practitioners and academic experts for identifying the most vital LSS barriers. After performing

two iterations of merging and removing those barriers have the same meaning. We finalize ten most signification barriers of LSS implementation. Dave, Muruges, & Devadasan, (2015) presented the literature review on LSS and identified the most common challenges in the implementation of LSS. The LSS implementation attempt in Indian healthcare sector has been presented by Bhat, Gijo, & Jnanesh, (2014), in the study, the authors presented the various challenges they face during LSS implementation. Antony, Krishan, Cullen, & Kumar (2012) have identified and present the challenges, barriers, success factors, tools/techniques of LSS for higher education institutions (HEIs). Psychogios, Atanasovski, & Tsironis (2012) investigate various issues related to the application of LSS in a service industry. Details of identified barriers are provided in Table I.

### 3. ISM AND FUZZY MICMAC METHODOLOGY AND MODEL DEVELOPMENT

Interpretive Structural Modeling (ISM) method was introduced by J.Warfield in 1974 to identify the relationship

among specific variables related to a complex problem or issue (Warfield, 1974). Manual methods are generally not clear when we have large numbers of variables and it becomes difficult to explain the interaction and inter-relationships among variables. ISM gives a clear understanding of all the variables and their relationship with other variables. So, when we have a complex issue and a systematic and logical thinking approach is required, then ISM is used. ISM is an interactive learning process in which a set of different and directly related variables of interest are arranged into a systematic hierarchical model known as a structural model for the solution of a complex problem and also provides a graphical representation based on the driving and dependent nature of the elements. Matriced Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) developed by Duperrin & Godet (1973). The MICMAC analysis helps to obtain the dependencies existing among the LSSBs. And to overcome the limitation of conventional MICMAC analysis, in this study Fuzzy MICMAC analysis have been utilized.

**TABLE 1: Identified LSSBs**

LSSBs No	LSSB	Literature support
1	Lack of management commitment	(Antony et al., 2012; Dave et al., 2015; Kumar, Kumar, & Haleem, 2015; Leseure, Hudson-Smith, Delgado, Ferreira, & Castelo Branco, 2010)
2	lack of knowledge about the methodology and lack of resources	(Bhat et al., 2014; Hess & Benjamin, 2015)
3	lack of knowledge concerning the LSS framework and project requirements	(Psychogios & Tsironis, 2012; Thomas, Barton, & Chuke-Okafor, 2008)
4	Lack of training	(Antony et al., 2012; Psychogios et al., 2012)
5	Culture which is not compatible for implementing LSS	(Antony et al., 2012; Lertwattanapongchai & William Swierczek, 2014; Psychogios et al., 2012)
6	Insufficient funds and improper fund allocation	(Psychogios et al., 2012; Thomas et al., 2008)
7	Lack of IT implementation and effective communication system	(Franchetti & Barnala, 2013; Kumar, Luthra, Govindan, Kumar, & Haleem, 2016)
8	Poor meeting of customer expectation	(Kumar et al., 2016; Psychogios et al., 2012; Snee, 2010)
9	Lack of project planning and management	(Thomas et al., 2008; van den Bos, Kemper, & de Waal, 2014)
10	Absence or insufficient integrated communication and cooperation between firm and their supplier	(Kumar et al., 2015; Psychogios & Tsironis, 2012)

#### 3.1 Interpretive Structural Modelling (ISM)

The various steps, which lead to the development of ISM model, are illustrated as given below.

- 1. Identification of variables:** The various barriers hinder the LSS implementation is identified from literature review, brain-storming and expert opinion.

The identified LSSBs and their appropriate codes are given. And details of literature support of these LSS barriers is provided in Table I.

- 2. Contextual relationship:** From the LSSBs identified in step 1, a contextual relationship is determined. The contextual relationship between the various LSSBs is established with help of expert opinion and brain

storming. This is useful for examining the pairs of variables. After the establishment of the contextual relationship, a structural self-interaction matrix (SSIM) is prepared based on the contextual relationship among variables. This SSIM represent the pair-wise relationship between each available variable. In SSIM the relationship between various variables is represented in the form of V, A, X and O.

Table II shows the self-interaction matrix (SSIM).

Where, V – for the relation from variable i to variable j.

A – for the relation from variable j to variable i.

X – for both direction relation from variable i to variable j and variable j to variable i.

O – If there is no direct relationship between variables i and j.

**TABLE 2: Structural self-interaction matrix**

LSSB no	10	9	8	7	6	5	4	3	2
1	V	V	V	V	V	V	V	V	V
2	V	X	V	V	A	X	X	A	
3	O	V	V	V	O	V	V		
4	V	X	V	V	A	X			
5	V	X	V	O	A				
6	V	V	V	V					
7	X	A	V						
8	A	A							
9	V								

3. **Initial Reachability Matrix (IRM):** Obtained SSIM is converted into binary matrix known as initial reachability matrix. This conversion is made by substituting symbols V, A, X and O by digit 0 and 1.

The substituting of symbols is carried out as per following rules.

If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.

If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.

If the (i, j) entry in the SSIM is X, then the (i, j) entry

in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.

If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Then initial reachability matrix is checked for transitivity for development of final reachability matrix (FRM). This transitivity of the contextual relationship is based on the assumption that if variable A is related to variable B and variable B is related to variable C, then variable A is necessarily related to variable C. The initial reachability matrix is shown in Table III and the final reachability matrix is shown in Table IV.

**TABLE 3: Initial reachability matrix**

LSSB no	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	1
2	0	1	0	1	1	0	1	1	1	1
3	0	1	1	0	1	0	1	1	1	0
4	0	1	0	1	1	0	1	1	1	1
5	0	1	0	1	1	0	0	1	1	1
6	0	1	0	1	1	1	1	0	1	1
7	0	0	0	0	0	0	1	1	0	1
8	0	0	0	0	0	0	0	1	0	0
9	0	1	0	1	1	0	1	1	1	1
10	0	0	0	0	0	0	1	1	0	1

**TABLE 4: Final reachability matrix**

LSSB no	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	1
2	0	1	0	1	1	0	1	1	1	1
3	0	1	1	0	1	0	1	1	1	1*
4	0	1	0	1	1	0	1	1	1	1
5	0	1	0	1	1	0	1*	1	1	1
6	0	1	0	1	1	1	1	0	1	1
7	0	0	0	0	0	0	1	1	0	1
8	0	0	0	0	0	0	0	1	0	0
9	0	1	0	1	1	0	1	1	1	1
10	0	0	0	0	0	0	1	1	0	1

4. **Level Partitions:** From the final reachability matrix, the reachability set and antecedent set for each LSSBs are found. The reachability set includes LSSBs itself and other LSSBs which may help to achieve. And the antecedent consist LSSBs and other LSSBs which may help in achieving it. Then, the intersection of these sets is identified for all available LSSBs. For LSSBs for which reachability and intersection sets are same is the top level LSSBs. Then, the same procedure is repeated until each LSSBs are identified for their respective levels. The level partition of each LSSBs is given in Table V.

**TABLE 5: Level of LSSBs**

LSSB no	Reachability set	Antecedent set	Intersection set	Level
1	1	1	1	V
2	2, 4, 5, 9	1, 2, 3, 4, 5, 6, 9	2, 4, 5, 9	III
3	3	1, 3	3	IV
4	2, 4, 5, 9	1, 2, 4, 5, 6, 9	2, 4, 5, 9	III
5	2, 4, 5, 9	1, 2, 3, 4, 5, 6, 9	2, 4, 5, 9	III
6	6	1, 6	6	IV
7	7, 10	1, 2, 3, 4, 5, 6, 7, 9, 10	7, 10	II
8	8	1, 2, 3, 4, 5, 7, 8, 9, 10	8	I
9	2, 4, 5, 9	1, 2, 3, 4, 5, 6, 9	2, 4, 5, 9	III
10	7, 10	1, 2, 3, 4, 5, 6, 7, 9, 10	7, 10	II

5. **Formation of ISM model:** To build ISM first the FRM is converted into the canonical matrix format by rearranging each LSSB according to their level. Then, the directed graph is drawn by means of nodes and arrow. This resultant directed graph also known as diagraph is converted into ISM by replacing nodes with appropriate statement of LSSBs. Then nodes are replaced by the statements of the LSSBs. This gives final ISM network. The diagraph is shown in Fig.1 and the final ISM model is shown in Fig. 2.

### 3.2 Fuzzy MICMAC methodology

For developing ISM model, the relationship between two LSSBs is denoted by 0 and 1. If there is no relationship between them then it is denoted by 0 and if there is the

relationship among them then it is denoted by 1. The relationship between LSSBs cannot be always same. Some relation may be strong, some may be very strong. To overcome this drawback of ISM model, fuzzy MICMAC analysis is used. Various steps for Fuzzy MICMAC are as below.

1. To obtain binary relationship matrix for Fuzzy MICMAC, the diagonal entries of FRM are converted to zero. Derived binary direct relationship matrix (BDRM) is shown in Table VI.
2. **Fuzzy Direct Reachability Matrix (FDRM):** Conventional MICMAC approach considers the only binary type of relationships. In this study Fuzzy approach is used to increase the sensitivity of

MICMAC. In Fuzzy MICMAC, an additional input of possible reachability is used. The possible reachability for variables is given in Table VII. Value With help of expert opinion the possible reachability for variables

is included in BDRM and fuzzy Direct Reachability Matrix (FDRM) is developed. The FDRM is shown in Table VIII.

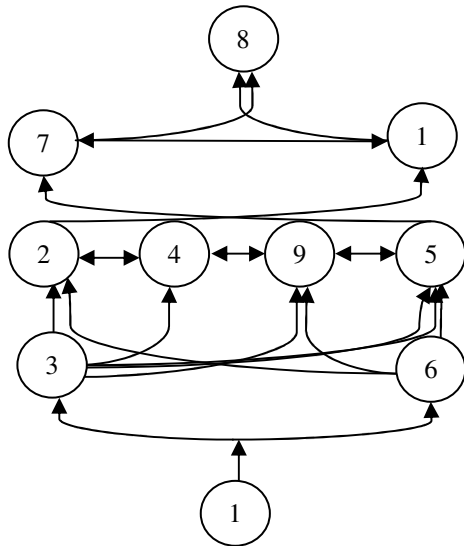


Fig. 1. ISM network

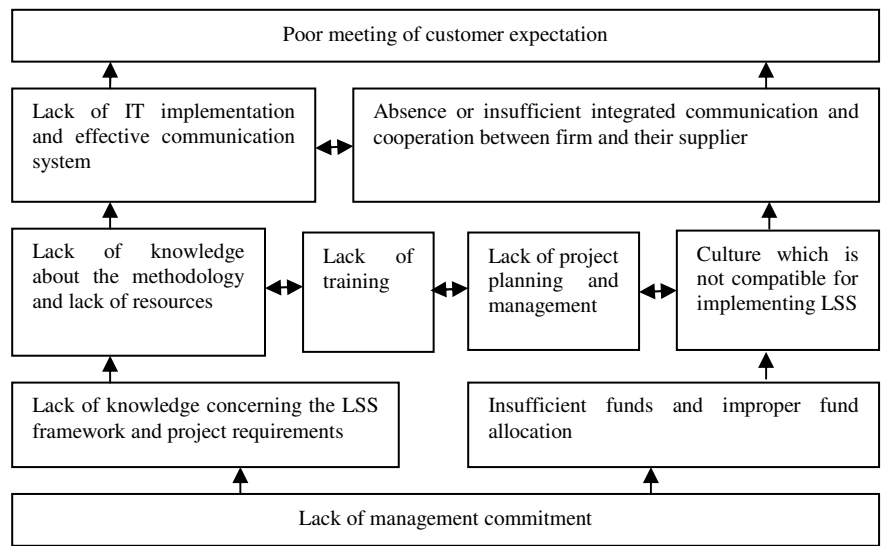


Fig. 2. ISM Model

TABLE 6: Binary direct reachability matrix

LSSB no	1	2	3	4	5	6	7	8	9	10
1	0	1	1	1	1	1	1	1	1	1
2	0	0	0	1	1	0	1	1	1	1
3	0	1	0	0	1	0	1	1	1	1*
4	0	1	0	0	1	0	1	1	1	1
5	0	1	0	1	0	0	1*	1	1	1
6	0	1	0	1	1	0	1	0	1	1
7	0	0	0	0	0	0	0	1	0	1
8	0	0	0	0	0	0	0	0	0	0
9	0	1	0	1	1	0	1	1	0	1
10	0	0	0	0	0	0	1	1	0	0

TABLE 7: Possible reachability

Possibility of reachability for BDRM	No	Very low	Low	Medium	High	Very high	Complete
Symbol	N	VL	L	M	H	VH	C
Value	0	0.1	0.3	0.5	0.7	0.9	1

3. **Fuzzy MICMAC Stabilized Matrix:** The FDRM is multiplied until the hierarchies of the driver and dependent power are stabilized. This multiplication follows the rule of fuzzy multiplication. Fuzzy multiplication is basically a generation of a Boolean

matrix Gorane and Kant, (2012). According to fuzzy set theory, when two matrices are multiplied then the product matrix is also a fuzzy matrix. This Fuzzy multiplication follows the below rule: Fuzzy multiplication.

$C = (A*B) = \max K [\min (a_{ik}, b_{kj})]$ , Where,  $A = [a_{ik}]$  and  $B = [b_{kj}]$

A stabilized matrix is shown in Table IX. The driving power of the LSSBs in fuzzy MICMAC is derived by addition of the entries of possible interaction in rows, and the dependent power of the LSSBs is determined by addition of the entries of possible interaction in columns.

**4. Categorization of LSSBs:** All LSSBs have been classified, based on their driving power and dependence power, into four categories as autonomous LSSBs, dependent LSSBs, linkages LSSBs, and driver LSSBs. In this classification of LSSBs, the first cluster consists autonomous LSSBs, which have weak driving power and also have weak dependence power.

**TABLE 8: Fuzzy direct reachability matrix**

LSSB no	1	2	3	4	5	6	7	8	9	10
1	0	0.9	0.5	0.7	0.7	0.9	0.5	0.5	0.7	0.7
2	0	0	0	0.3	0.5	0	0.5	0.5	0.5	0.7
3	0	0.5	0	0	0.7	0	0.7	0.7	0.7	0.9
4	0	0.5	0	0	0.5	0	0.3	0.5	0.7	0.7
5	0	0.3	0	0.3	0	0	0.5	0.3	0.7	0.7
6	0	0.7	0	0.9	0.7	0	0.5	0	0.5	0.7
7	0	0	0	0	0	0	0	0.5	0	0.7
8	0	0	0	0	0	0	0	0	0	0
9	0	0.5	0	0.5	0.5	0	0.5	0.7	0	0.7
10	0	0	0	0	0	0	0.7	0.7	0	0

**TABLE 9: Fuzzy MICMAC stabilized matrix**

LSSB no	1	2	3	4	5	6	7	8	9	10	Driving
1	0	0.9	0.9	0.9	0.9	0.9	0.7	0.9	0.9	0.9	7.9
2	0	0	0	0.5	0.7	0	0.7	0.7	0.5	0.7	3.8
3	0	0.9	0	0	0.7	0	0.9	0.7	0.9	0.9	5
4	0	0.5	0	0	0.7	0	0.5	0.7	0.9	0.9	4.2
5	0	0.7	0	0.3	0	0	0.7	0.5	0.7	0.7	3.6
6	0	0.9	0	0.9	0.9	0	0.7	0	0.7	0.7	4.8
7	0	0	0	0	0	0	0	0.5	0	0.7	1.2
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0.5	0	0.5	0.5	0	0.5	0.9	0	0.7	3.6
10	0	0	0	0	0	0	0.7	0.9	0	0	1.6
Dependence	0	4.4	0.9	3.1	4.4	0.9	5.4	5.8	4.6	6.2	

Second cluster consist dependent LSSBs, which have strong dependence power and weak driving power. The third cluster consist linkage LSSBs, which have strong driving power and also have strong dependence power. The forth cluster consist driver LSSBs which have strong driving power and weak dependence power. Fig.3 shows the Cluster of LSSBs.

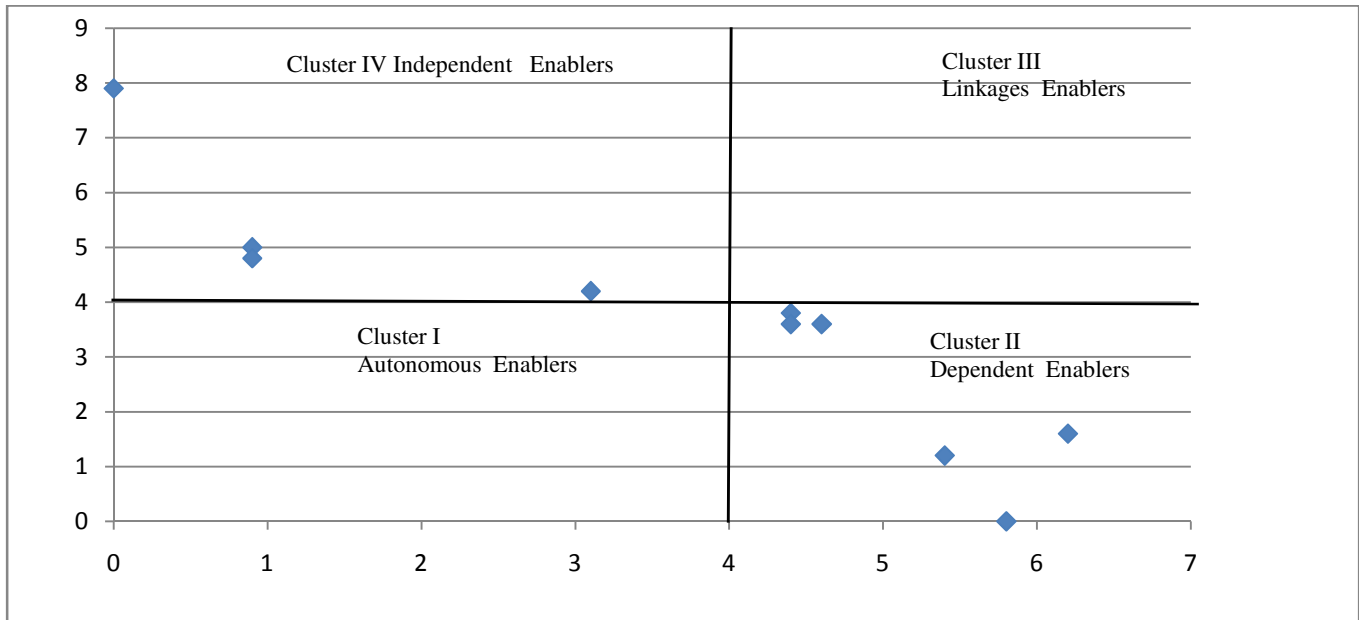


Fig. 3. Cluster of LSSBs

#### 4. RESULT AND DISCUSSION

From Fig. 2 it is shown that ISM network consist five levels. 'Poor meeting of customer expectation' is top level LSSB. On the second level of ISM hierarchy 'Lack of IT implementation and effective communication system' and 'Absence or insufficient integrated communication and cooperation between the firm and their supplier' are there. While 'Lack of knowledge about the methodology and lack of resources', 'Lack of training', 'Culture which is not compatible for implementing LSS' and 'Lack of project planning and management' are at level three. On level four two LSSBs are there namely 'Lack of knowledge concerning the LSS framework and project requirements' and 'Insufficient funds and improper fund allocation'. And 'Lack of management commitment' is last level LSSB.

From Fuzzy MICMAC analysis, all LSSBs can be classified based on driving-dependence power.

##### 4.1 Autonomous LSSBs

From a cluster of LSSBs there are no autonomous LSSBs in this system. Autonomous LSSBs have weak driving power and also have weak dependence power. The autonomous LSSBs are relatively disconnected from the system, hence any change in autonomous LSSBs do not have much more effect on ISM network.

##### 4.2 Dependent LSSBs

From cluster of LSSB, lack of knowledge about the methodology and lack of resources, culture which is not compatible for implementing LSS, lack of IT implementation and effective communication system, poor

meeting of customer expectation, lack of project planning and management and absence or insufficient integrated communication and cooperation between firm and their supplier are fall under cluster of dependent LSSB. These LSSBs have weak driving power and strong dependence power. That means the change in dependence LSSBs have does not much more effect on ISM, and change in driver LSSBs have much more effect on dependence LSSB. They are seen at the top level of the ISM hierarchy. Their strong dependence power indicates that they require all other LSSBs to overcome their effect.

##### 4.3 Linkage LSSBs

There is no linkage LSSBs is available in this system. Linkage LSSBs have high driving power and also have high dependence power. That means a change in linkage LSSBs have the effect on other LSSBs and also have the effect on themselves. They are unstable in nature. Linkage LSSBs may affect the system either in a positive or negative way.

##### 4.4 Driver LSSBs

From above cluster of LSSBs following LSSBs are the driver LSSBs for this system: lack of management commitment, lack of knowledge concerning the LSS framework and project requirements, lack of training and insufficient funds and improper fund allocation. They have strong dependence power means a change in these driving LSSBs has significant effect on ISM network. Driving LSSBs are key variables to controlling the ISM hierarchy. In ISM network they are at the bottom level of ISM hierarchy.

## 5. CONCLUSION

From an extensive literature review and a discussion with the expert team, we have identified total twenty-three LSS implementation barriers out of which ten LSSBs is finalised for this study. The purpose of this study is to understand the interactions among these LSSBs using ISM and fuzzy MICMAC analysis. The major contribution of this paper lies in the development of contextual relationships among identified LSSBs through a systematic framework. The present paper provides an ISM-fuzzy MICMAC-based model to understand the relationships among identified LSSBs. ISM methodology is used to develop a map of the complex relationships among various LSSBs. Through the ISM-based hierarchical model, it is observed that the poor meeting of customer expectation exists at the top level in the ISM hierarchy. Lack of management commitment is at the base of this model. Policy-makers should give appreciable consideration to the LSSBs that exist at the base of the hierarchy. The results of the ISM are used as an input to the fuzzy MICMAC analysis to identify the driving power and dependence of LSSBs. The organization should give more focus towards to overcome the driving LSSBs so as to manage the dependent LSSBs for a successful implementation of LSS.

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# Study of Different Parameter in Advance Machining Process

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**Abstract:** Since beginning of the human progress, people have evolved tools and energy sources to power these tools to meet the requirements for making the life easier and enjoyable. In twentieth century products were made from the most durable and consequently, the most unconventional methods. In an effort to meet the manufacturing challenges created by these methods, tools have now evolved to include materials such as alloy steel, carbide, diamond and ceramics. The greatly improved thermal, chemical, and mechanical properties of the new engineering materials made it impossible to machine them using the traditional machining processes of cutting and abrasion.

In modern machining practice, harder, stronger, and tougher materials that are more difficult to cut are frequently used. More attention is, therefore, directed toward machining processes where the mechanical properties of the work piece material are not imposing any limits on the material removal process. These methods play a considerable role in the aircraft, automobile, tool, die, and mold making industries.

During the last 55 years, over 20 different non-traditional manufacturing processes have been invented and successfully implemented into production. The non-conventional manufacturing processes are not affected by hardness, toughness or brittleness of material and can produce any intricate shape on any work piece material by suitable control over the various physical parameters of the processes.

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## 1. REVIEW OF LITERATURE

Abrasive water jet cutting is an extended version of water jet cutting; in which the water jet contains abrasive particles such as silicon carbide or aluminium oxide in order to increase the material removal rate above that of water jet machining. Almost any type of material ranging

From hard brittle materials such as ceramics, metals and glass to extremely soft materials such as foam and rubbers can be cut by abrasive water jet cutting. The narrow cutting stream and computer controlled movement enables this process to produce parts accurately and efficiently. This machining process is especially ideal for cutting materials that cannot be cut by laser or thermal cut. Metallic, non-metallic and advanced composite materials of various thicknesses can be cut by this process. This process is particularly suitable for heat sensitive materials that cannot be machined by processes that produce heat while machining.

**Dr. N. Mohana Sundara Raju** With reference to "Analysis of surface roughness in abrasive water jet cutting of cast iron" Surface roughness is one of the most important criteria, which help us determine how Rough a work piece material is machined. By analyzing the experimental data of the selected material, it has been found that the optimum selection of the four basic Parameters, i.e., water pressure, abrasive mass flow rate, nozzle traverse speed and Nozzle

standoff distance are very important on controlling the process outputs such as surface roughness.

**Derzija Begic-Hajdarevic et al.** studied the effects of material thickness, traverse speed and abrasive mass flow rate during abrasive water jet cutting of aluminum on surface roughness. They analyzed that traverse speed has great effect on the surface roughness at the bottom of the cut and the correlation between the surface roughness and other abrasive water jet cutting variables.

**Introduction: -** There are three major areas classified under advanced machining processes. These streams are mechanical, thermo-electrical and electro-chemical. One of such important mechanical advanced machining process is Abrasive Water Jet (AWJ) machining. The abrasive water jet machining process does not generate any heat because of which there are not heat affected zones and residual stresses during the surface generation process. The inherent characteristic of the process is that it is non-contact and dynamic cutting process. The other notable benefits include thin kerf width,

Negligible heat affected zone, and flexibility during material removal. Various classes of Abrasives are usually applied during AWJ machining like garnet, olivine, aluminum oxide (Al₂O₃), silica-sand, glass bead, silicon carbide (SiC), zirconium, etc. There are several advantages of abrasive water jet machining process such as no thermal alterations; flexibility in machining, larger applicability

besides very small cutting forces. There are several distinguished advantages of AWJ technique. It is less sensitive to material properties and hence does not cause chatter, has no thermal effects, imposes minimal stresses on the work piece, and has high machining versatility and flexibility. It has been always challenging to incorporate constricted

Tolerances on the components and parts machined using the process. In addition to the materials

Having superior properties, the machining quality can also be extended for the applications

The apparatus of water jet machining consists of the following components:

- 1) **Reservoir:** It is used for storing water that is to be used in the machining operation
- 2) **Pump:** It pumps the water from the reservoir. High pressure intensifier pumps are used to pressurize the water as high as 55, 000 psi. For the abrasive water jet, the operating pressure ranges from 31, 000 to 37, 000 psi. At this high pressure the flow rate of the water is reduced greatly.
- 3) **Intensifier:** It is connected to the pump. It pressurizes the water acquired from the pump to a desired level.
- 4) **Accumulator:** It is used for temporarily storing the pressurized water. It is connected to the flow regulator through a control valve.
- 5) **Control Valve:** It controls the direction and pressure of pressurized water that is to be supplied to the nozzle.
- 6) **Flow regulator:** It is used to regulate the flow of water.
- 7) **Nozzle:** It renders the pressurized water as a water jet at high velocity. Once the water is pressurized, it is forced through a sapphire nozzle which is composed of the natural sapphire stone due to the strength of the stone. The diameter of the nozzle can be varied depending on the application for which the water jet is being used. A damaged nozzle leads to poor cohesion of the stream, thereby reducing the cutting ability greatly. The nozzle typically lasts 100 to 200 hours before it needs to be replaced.
- 8) **Mixing Tube:** The stream of water which emerges from the nozzle is then mixed with the abrasive. This takes place in the mixing tube, which is usually constructed out of tungsten-carbide. Wear of the mixing tube, due to the abrasive, is a problem and it needs frequent replacement. When the tube becomes

worn, the jet no longer is cohesive and loses power and cutting ability rapidly.

- 9) **Catchers:** After the cut has been made, the water abrasive material is collected in a catcher. In a field situation there are still problems catching the waste material. Often catchers need to be custom designed for a specific job

AWJC process is significantly affected by the Process tuning parameters .There are numerous associated parameters in this technique, among which are as follows.

1. Abrasive mass flow rate
  2. Nozzle tip distance
  3. Gas Pressure
  4. Velocity of abrasive particles
  5. Mixing ratio
  6. Abrasive grain size
- 1) **Abrasive mass flow rate:** - Mass flow rate of the abrasive particles is a major process parameter that influences the metal removal rate in abrasive jet machining. In AJM, mass flow rate of the gas (or air) in abrasive jet is inversely proportional to the mass flow rate of the abrasive particles. Due to this fact, when continuously increasing the abrasive mass flow rate, Metal Removal Rate (MRR) first increases to an optimum value (because of increase in number of abrasive particles hitting the work piece) and then decreases. However, if the mixing ratio is kept constant, Metal Removal Rate (MRR) uniformly increases with increase in abrasive mass flow rate.
  - 2) **Nozzle tip distance:** Nozzle Tip Distance (NTD) is the gap provided between the nozzle tip and the work piece. Up to a certain limit, Metal Removal Rate (MRR) increases with increase in nozzle tip distance. After that limit, MRR remains constant to some extent and then decreases. In addition to metal removal rate, nozzle tip distance influences the shape and diameter of cut. For optimal performance, a nozzle tip distance of 0.25 to 0.75 mm is provided.
  - 3) **Gas Pressure:** Air or gas pressure has a direct impact on metal removal rate. In abrasive jet machining, metal removal rate is directly proportional to air or gas pressure.
  - 4) **Velocity of abrasive particles:** Whenever the velocity of abrasive particles is increased, the speed at which the abrasive particles hit the work piece is increased. Because of this reason, in abrasive jet machining, metal removal rate increases with increase in velocity of abrasive particles.

- 5) **Mixing ratio:** Mixing ratio is a ratio that determines the quality of the air-abrasive mixture in Abrasive Jet Machining (AJM). It is the ratio between the mass flow rate of abrasive particles and the mass flow rate of air (or gas). When mixing ratio is increased continuously, metal removal rate first increases to some extent and then decreases.
- 6) **Abrasive grain size:** Size of the abrasive particle determines the speed at which metal is removed.

**Experimental setup:** - Considering all parameters of Water jet machining we focus on abrasive material in terms of Mixing ratio and size-type of abrasive practical. Based on the application situations, work material consider Stainless Steel Type 316.

#### Work Material

Stainless steel type 316 is part of a family of stainless steel alloys (301, 302, 303, 304, 316, 347). The 316 family is a group of austenitic stainlesssteels with superior corrosion resistance to 304 stainless steel. This alloy is suitable for welding because it has a carbon content lower than 301 to 303 series alloys to avoid carbide precipitation in welding applications.

Stainless Steel 316		
Nominal Composition in Percentage:		
Sr No	Element Content	Percentage
1	Ni	12
2	Cr	17
3	Mo	2.5
4	Fe	Balance
5	Si	1
6	Mn	2
7	Cr	0.08
8	P	0.045
9	S	0.03

#### Parametric Study

Abrasive practical: - Geometry, hardness and size can be considered the most important characteristics affecting the wear rate caused by abrasive particles. The combined effect of these characteristics on wear has not yet been modeled as a whole. One particular model, proposed by Rabinowicz et al. (1961), involves a single particle being considered as a pointed tool, so that the effect of the geometry can be determined.

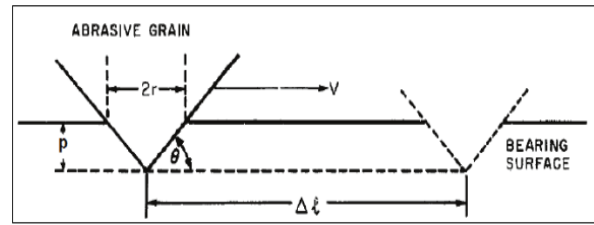


Fig. 1. Conical abrasive particle cutting a groove of depth  $p$ , and sliding for a distance  $\Delta l$  to produce a wear volume  $V$  (Rabinowicz et al., 1961).

The wear rate is expressed as follows:

$$\frac{dV}{dl} = \frac{\tan \theta}{H} W$$

- 1) **Tan  $\theta$ :** - is the average tangents of all roughness angles of the abrasive particles,
- 2) **H** is the hardness of bearing surface
- 3) **W** is the total load.

In this case the particle is considered to be a solid body that neither degrades nor changes Size and whose properties remain constant throughout the whole wear process. This Hypothesis is not verified, especially for those situations where the hardness of abrasive is Lower than the abraded material. This situation led to small wear rates, and it is usually classified as mild wear (Gates, 1998). The fragmentation of particles depends on their

Fracture toughness, and it is possible to verify in the literature data that the higher the hardness, the higher the fracture toughness (Fig.) Therefore, for softer abrasives the breakage is easier.

## 2. RESULT AND DISCUSSION

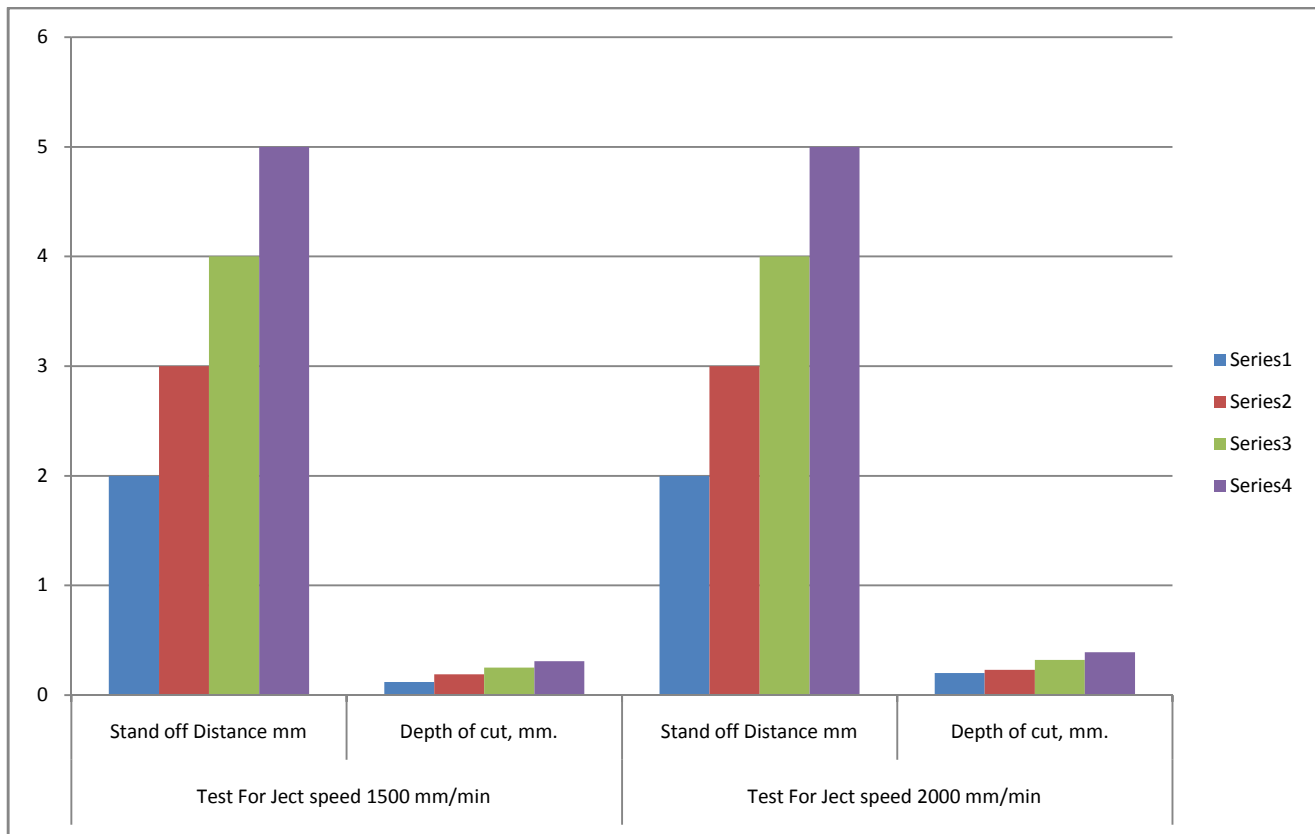
Experiment was conducted to analysis the parameter, some result was concluded on given experimental setup. Value of set variable are as follow Water/jet Pressure 100Mp, Jet travel speed was 1000 to 2000 mm/Sec, Stand-off distance of 2mm.

### 1) Effect of standoff distance on depth of cut :-

The depth of cut was measure with changing standoff distance for Speed at 1500mm/min and 2000 mm/min.

Test For Jet speed 1500 mm/min		Test For Jet speed 2000 mm/min	
Stand off Distance mm	Depth of cut, mm.	Stand off Distance mm	Depth of cut, mm.
2	0.12	2	0.2
3	0.19	3	0.23
4	0.25	4	0.32
5	0.31	5	0.39

Effect were seen where standoff distance increases also increases the depth of cut.



**Fig. 2. The effect of stand-off distance on depth of cut**

- 2) **Effect of Travel speed on depth of cut:** -Test were conducted for different speed of jet at abrasive flow rate 100 g/min and 150 g/min depth of cut was calculated. Are shown in table.

Abrasive flow rates of 100 g/min.		Abrasive flow rates of 150 g/min.	
Traverse speed mm/min	Depth of cut, mm.	Traverse speed mm/min	Depth of cut, mm.
1000	0.8	1000	0.6
1100	0.76	1100	0.57
1200	0.72	1200	0.53
1300	0.66	1300	0.51
1400	0.62	1400	0.48
1500	0.6	1500	0.42
1600	0.58	1600	0.3
1700	0.55	1700	0.28
1800	0.52	1800	0.25
1900	0.49	1900	0.24
2000	0.45	2000	0.22

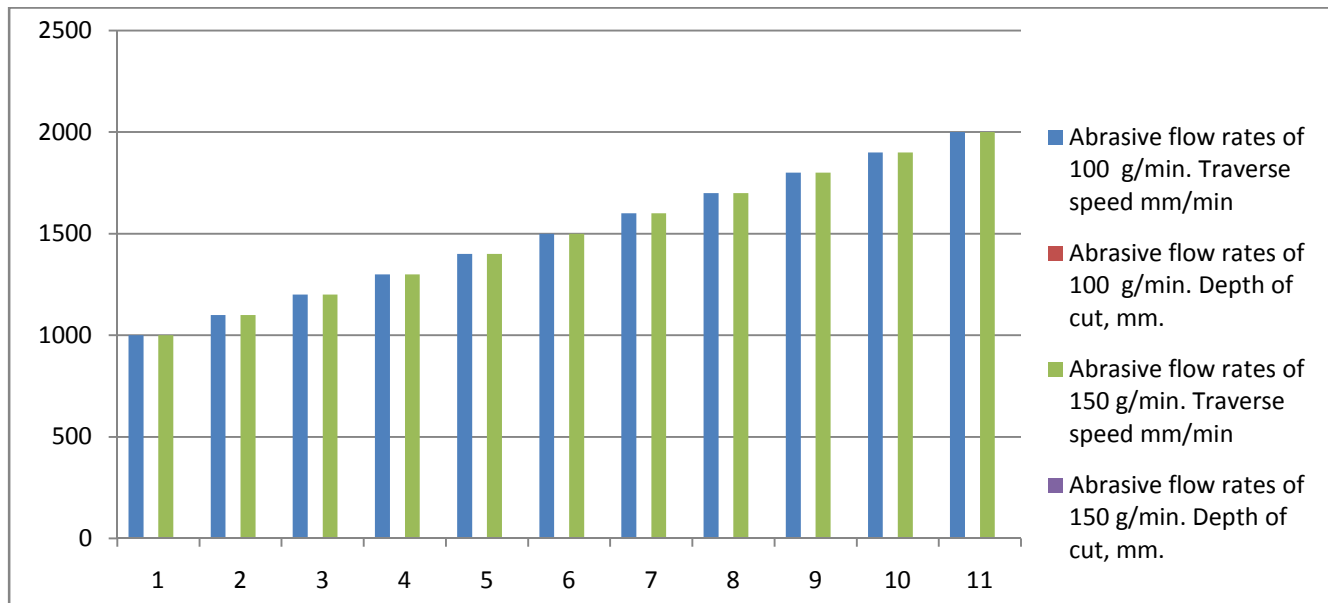


Fig. 3. The effect of Travel speed on depth of cut

- 3) **Effect of abrasive flow rate on depth of cut :-**Test were conducted on abrasive flow rate 100gm/min to 150 gm/min and some result were calculated on two different jet speed at 1500 mm/min and 2000 mm/min.Relation between the variable are shown in fig-

Test For Jet speed 1500 mm/min		Test For Jet speed 2000 mm/min	
Abrasive flow rategm/min	Depth of cut, mm.	Abrasive flow rate gm/min	Depth of cut, mm.
100	0.12	100	0.2
110	0.19	110	0.23
120	0.25	120	0.32
130	0.31	130	0.39
140	0.36	140	0.43
150	0.42	150	0.48

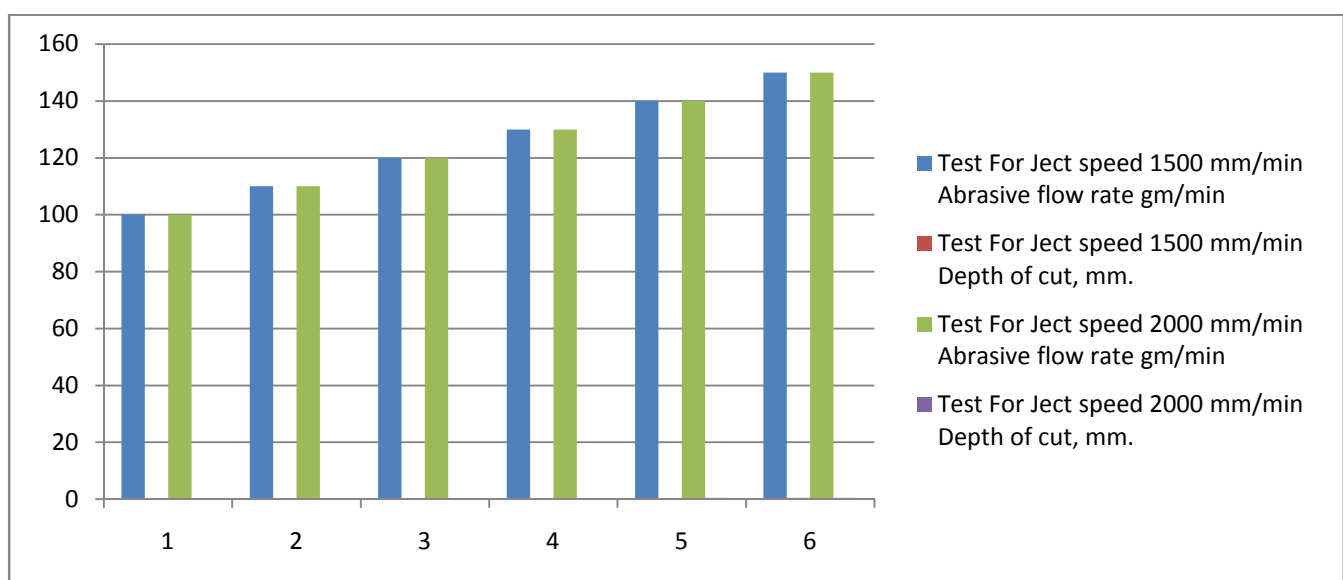


Fig. 4. The effect of abrasive flow rate on depth of cut

### 1) Effect of standoff distance on Material Removing Rate

Test was conducted on different standoff distance changing from 2, 3, 4, 5mm and check Material removal rate are as shown in table

Test For Ject speed 1500 mm/min		Test For Ject speed 2000 mm/min	
Stand off Distance mm	Material removal rate mm3/min	Stand off Distance mm	Material removal rate mm3/min
2	82	2	90
3	84	3	92
4	83	4	91
5	86	5	93

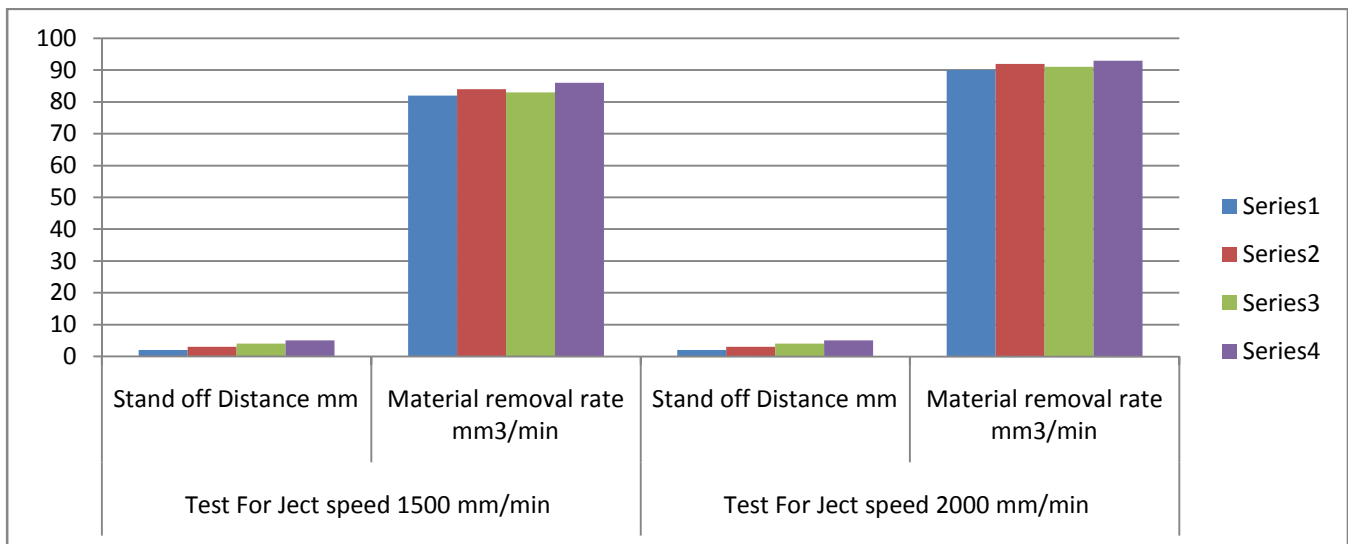


Fig. 5. Effect of standoff distance on Material Removing Rate.

### 2) Effect of Travel Speed on Material Removing Rate

Test were conducted on two type of abrasive flow rate 100 g/min and 150 g/min it was found that traverse speed increases Material removal rate is decreases as shown in table

Abrasive flow rates of 100 g/min.			Abrasive flow rates of 150 g/min.		
Traverse speed mm/min	Material removal rate mm3/min		Traverse speed mm/min	Material removal rate mm3/min	
1000	112		1000	156	
1100	107		1100	148	
1200	96		1200	143	
1300	85		1300	137	
1400	73		1400	122	
1500	68		1500	119	
1600	62		1600	102	
1700	58		1700	96	
1800	53		1800	88	
1900	52		1900	76	
2000	51		2000	68	

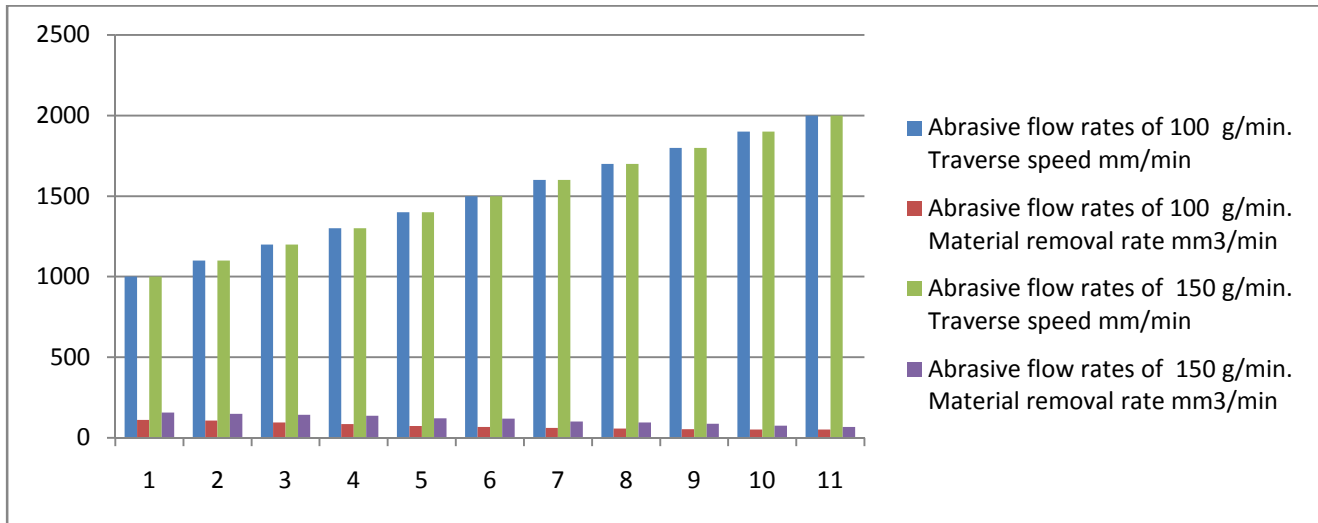


Fig. 6. Effect of Travel Speed on Material Removing Rate.

### 3) Effect of abrasive flow rate on Metal Removing Rate:-

Test were conducted to find out the effect of abrasive flow rate on material removing rate, with two speed at 1500 mm/min and 2000 mm/min table show the details of same.

Test For Ject speed 1500 mm/min		Test For Ject speed 2000 mm/min	
Abrasive flow rate gm/min	Material removal rate mm3/min	Abrasive flow rate gm/min	Material removal rate mm3/min
100	80	100	92
110	92	110	96
120	103	120	110
130	112	130	123
140	123	140	134
150	132	150	141

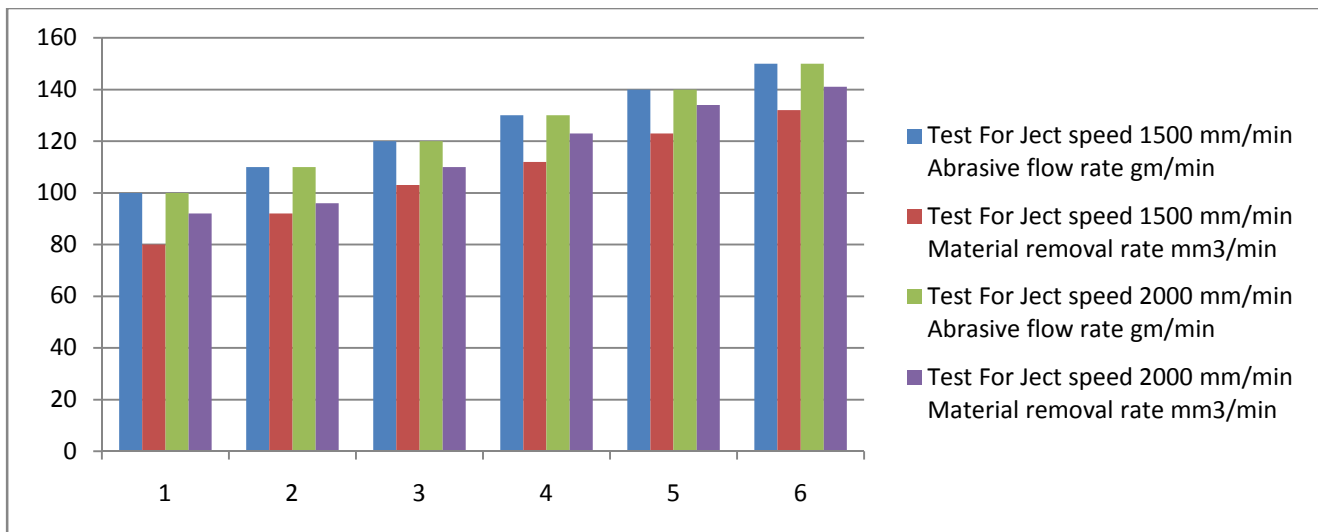


Fig. 7. Effect of Travel Speed on Material Removing Rate



### 3. CONCLUSION

To achieve this objective a series of tests were conducted using an industrial AWJ machine to generate rectangular Slot in steel alloy as a specimen. The considered process parameters are depth of cut, and metal removal rate. The considered process variables are traverse speed, jet pressure, abrasive flow rate and stand-off distance. The summary of the results is shown in Table

Summary of the effects of AWJ process variables on process parameters			
Process variable	Process variable range	Effect of variable increase on process parameters	
		Depth of cut	MRR
Traverse speed	From 1000 to 2000 mm/min	Decrease	Decrease
Abrasive flow rate	From 100 to 150 g/min.	Increase	Increase
Stand-off distance	2, 3, 4, 5 mm	No effect	No effect

The above table shows that some process erratic has no effect on process restriction this yields to discard these variables in any process control operation, In addition, this result has an important effect on selecting or designing AWJ machines for slotting Operations. Since the stand-off distance has no noticeable effect on process parameters, it is better to select a longer value to prevent the nozzle front from damaging by the reflection of the water stream and abrasive.

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# A Literature Review to Identify Defects in SMAW Welding and its Parameter

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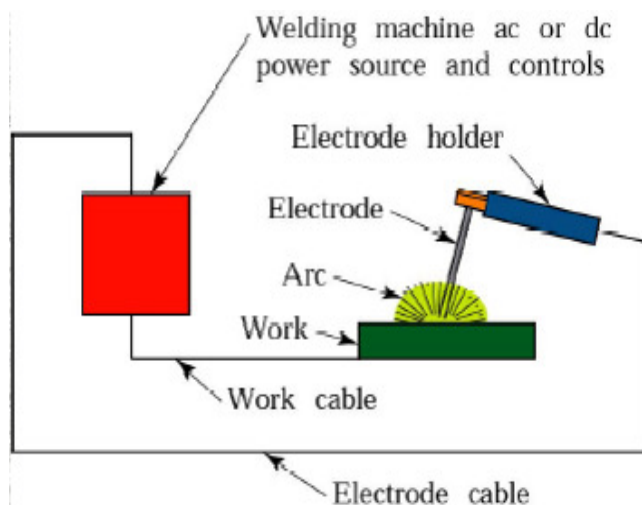
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**Abstract:** The aim of this paper is to identify the different types of defects occur in SMAW (Shielded Metal Arc Welding) welding process. A literature review is made to find the SMAW process parameter. SMAW is one of the metal joining processes. It is widely used process for fabrication, and industrial purpose. Performance of welding is depending on quality of welding. It is mainly affected by the defect in weld profile. Defects occur in weld profile are porosity, holes, incomplete penetration, incomplete fusion, crack etc. The identified welding process parameters are welding current, arc voltage, electrode angle, welding speed, and wind velocity. For doing the literature review seven papers from reputed journals and the relevant workshops review are used.

**Keywords:** SMAW, Welding parameters, Defects, literature review.

## 1. INTRODUCTION

The Shielded Metal Arc Welding (SMAW) is very flexible, portable, versatile, and having low cost process of metal joining by fusion of material. The working process of SMAW is very simple than other welding process. The arc is created between electrode tip and work piece when current is supply. Which causes heat generation about 6500°F due to this metal is melted and metallurgical bond is formed. The SMAW process is very much useful to join mild steel material.



**Fig. 1. Working of SMAW process**

The strong joint of mild steel plate is done by the SMAW process (S.M.Ravikumar, Dr.P.Vijian, 2014). Among all the other process of welding SMAW is very versatile and

important because having advantage of having compact and small setup of equipment so it is easily shifted. The cost of equipment of SMAW process is very less. SMAW is the manual welding process which is also called as stick or cover electrode welding process because the consumable electrode used in process having the cover of flux powder around it (S.M.Ravikumar, Dr.P.Vijian, 2014). Other than casting, riveting, friction welding SMAW is more economical and much faster process of joining metals. This process find almost 50% of total application in industries because it is very flexible having a wide variety of electrodes. It makes possible to weld number of alloys. To get the desired weld it is essential to know the interrelationship between parameter. The weld bead geometry is mainly deciding the quality of weld. It is achieve by considering best setting of input parameter.

The performance of welding process is mainly depending on the values of their parameter with respect to specification of material. It affects the strength, repairing cost and productivity. Mainly there are two type of welding parameter controllable and uncontrollable parameter of welding. Welding current, Arc voltage, electrode to work piece angle, Root gap, weld metal deposition, weld speed are the controllable parameter of SMAW. Weld bead dimension, Heat affected zone, weld penetration are the uncontrollable parameter of SMAW (Raghavendra N and Dileep Kumar, 2015). The welding process parameter setting is mainly affecting the quality of weld and the type of defect which occur in welding are incomplete fission, crack, weld bead geometry, incomplete penetration, holes, porosity. There are various method to identify the defects in welding which are destructive and non-destructive method of inspection are radiographic inspection, ultrasonic

inspection, vision inspection, magnetic detection and online computer vision inspection of weld bead by using sensor (Gang Wang, T. Warren Liao, 2001; S.M. Tabatabaeipour, F. Honarvar, 2010).

## 2. LITRATURE REVIEW

### 2.1 From journals

Raghavendra N and Dileep Kumar (2015) discuss to optimize the process for joining of pipe so that there is continuous and leak proof joint by the SMAW process. The experiments were done on the steel pipes having diameter of 48mm and the wall thickness 3mm. The Taguchi method is applied to optimize the process by using different parameters of SMAW process are welding current, welding speed, root gap and position of electrode base in the range of 80-100 amp, 4-6 rpm, 30-60 deg, 0-1.5mm respectively. The output result i.e. leakage of joint is measured by hydraulic hand pump of capacity 400 bars, at 30 bars. After the experiment it is found that the leakage in pipes when welding current at 90 amp and all three parameter are at low level. Also the leakage is present in pipe when the angle of electrode is at highest level i.e. at 90deg. So the two factor welding current and the electrode angle are more significant for leak proof joint of pipe.

S. M.Ravikumar, Dr.P.Vijian (2014) work on improving the quality of weld bead geometry of the SMAW process. The study of process is done on the mild steel plate IS2062 having dimensions 100mm×50mm×6mm and E6013 electrode having 3.5mm diameter. To optimize the process they uses Taguchi DOE with L9 OA. The various input parameter used in the experiment are welding current, welding speed and additional parameter wind velocity. The ranges of parameter used are 100-140 amp, 2-4mm/s, 3-7m/s respectively The output parameter measured are the dimensions of weld bead profile by process of etching, after completion of welding with the specification of OA decide. Then cut the sample at the midpoint such that the weld pool is perpendicular to the cut. Then the specimen are prepared by metallurgical polishing and etching it with 5% nital solution after this the weld bead profile is measured by the optical microscope (10X) in the form of width(W), penetration(P), reinforcement(R).they uses the Greay relation analysis to find the optimal solution which are welding current(140 amp), welding speed (4mm/s), and wind velocity(7m/s) and the significance of parameter in process are welding current(47.71%), welding speed (30.40%), and wind velocity(19.54).

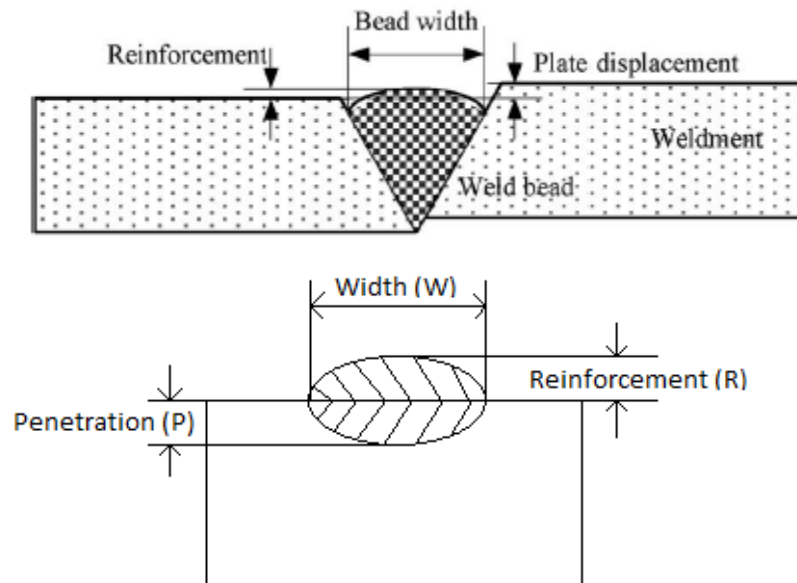
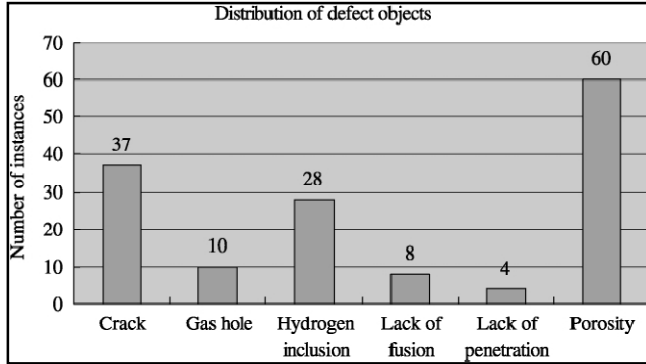


Fig. 2. Weld profile

R.P. Singh, R.C. Gupta and S.C. Sarkar(2012) discuss about the effect of magnetic field on with different parameter on penetration the experiment was done on the mild steel plate having dimension of 150 mmx50 mmx5 mm butt joint, steel electrodes of 3.15 mm diameter by using SMAW process. The different parameters and their ranges used are welding current (90-110Amp), arc voltage (20-24V), welding speed (40-80mm/min), and external

magnetic field (0-80Gauss) and to measure the output parameter by etching the cut part, dipped in mixture of 2% nitric acid and 98% ethyl alcohol solution and then measured the dimension. The analysis was done with the help of artificial neural network. The magnetic field decrease the depth of penetration. The more penetration is at 100 A current, 22 V voltage, 40 Gauss magnetic field and 40mm/min welding speed.



**Fig. 3. Distribution of welding defects in the test data**

Gang Wang, T. Warren Liao(2001) discuss about the identification of different defects of welding by the radiographic image processing. The three main step in the radiographic testing are digital image processing, feature extraction, and pattern classification. These techniques differentiate the defect from pattern by changing the contrast. Dimensions are measured by measuring distance from centre, radius, major axis, width etc. The X-ray film strip used is about 3.5 in. wide and 17 in long, digitized about 70 $\mu$ m. The object is digitized by the NDT SCAN II digitizer. The different types of defect measured by the author are crack, gas hole, lack of fusion, lack of penetration, porosity. How much this defects are present is shown in graph.

S.M. Tabatabaeipour, F. Honarvar(2010) do their work to identify different behaviour of the base material (AISI 316L) welds of two process GTAW and SMAW by using the ultrasonic testing. The dimensions of the base material are thickness of base material, root face, and root gap were 25, 2, and 2mm, respectively were selected. First the defect is measured by the X-ray radiography then the ultrasonic time-of-flight diffraction is applied on specimen 6MHz

longitudinal angle beam probes is used in the experiment. Ultrasonic waves are applied from various direction and longitudinal wave mode, Shear wave mode are measured. It is found that the defect of SMAW is clearly observed in B-scan image but the defect of GTAW is not, because of the grain size.

J. Edwin Raja Dhasa, S. Kumanan(2011) discuss about the weld quality which is describe by the weld bead geometry, deposition rate and hardness by submerge arc welding. These parameter are affected by the input parameter which are consider by author are welding current, welding speed, arc voltage and electrode stickout. To get the decided objective Taguchi and nonconventional technique such as genetic algorithm (GA) and particle swarm optimization (PSO) are used. The experiment was done on 500mm $\times$ 50 mm $\times$ 6 mm mild steel plate by using the ER70S-6 copper coated electrode. I/P parameter used in the range of welding current (360-390A), welding speed(400-420mm/min), arc voltage(25-26V) and electrode stickout(19-25mm).it is found that the optimization process PSO does not give any model of optimization. Therefore this process is best welding shop floor environment.

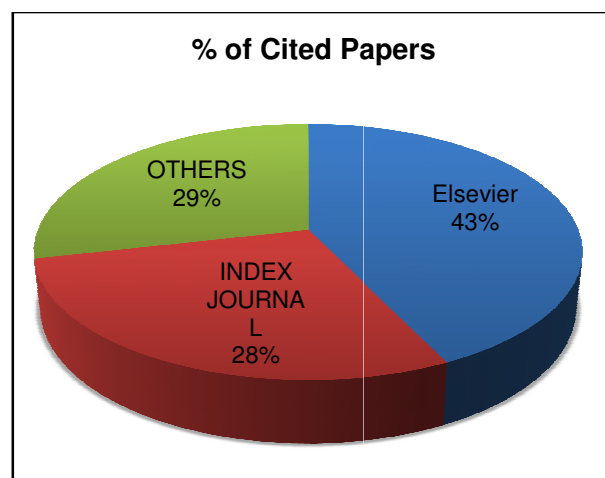
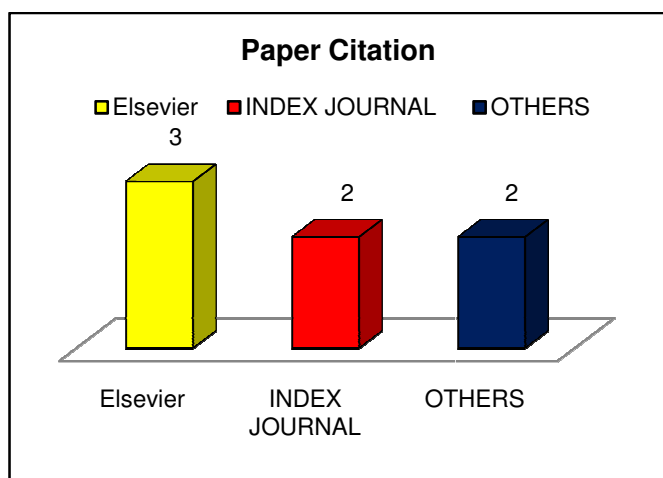
S. Kumanan, J. Edwin Raja Das(2007) do their work to identify the weld quality by measuring the different weld bead dimension (bead width, bead reinforcement, depth of penetration and bead hardness, holes) of the SAW process, and optimize the welding parameter by using Taguchi DOE and regression analysis. The work is done on mild steel plate with 500mm $\times$  50mm $\times$  6mm with square butt joint and having 1mm root gap by using SAW process. The different working parameter used are welding current, arc voltage, welding speed, and electrode stickout in the range of 360-390 amp, 25-26 volt, 400-420 mm/min, 19-25mm respectively. The weld bead geometry is measured by cutting 10mm width samples, polish it and etched. Hardness is measured by Rockwell hardness.

**TABLE 1: Summary of Literature Review**

Sr. no	Title	Author	Journal	Finding
1.	An Experimental Study and Optimization of Shielded Metal Arc Welding Parameters for Welding of Pipes by Using Taguchi Approach	Raghavendra N Dileep Kumar	European Journal of Advances in Engineering and Technology, 2015	Defects of leakage in pipes having wall thickness 3mm Parameters used are welding current, welding speed, root gap and position of electrode in the range of 80-100 amp, 4-6 rpm, 30-60 deg, 0-1.5mm respectively.
2.	Optimization of weld bead geometry in Shielded Metal Arc Welding using Taguchi Based Grey Relational Analysis	S.M. Ravikumar, Dr. P. Vijian	International Journal of Mechanical & Mechatronics Engineering 2014.	The defects in weld geometry if mild steel plate having dimension 100 mm $\times$ 50mm $\times$ 6 mm in the form of penetration, reinforcement, width by using parameter welding current, welding speed and additional parameter wind velocity in the range of 140 amp, 4 mm/s, 7 m/s respectively.

Sr. no	Title	Author	Journal	Finding
3.	The Effect of Process Parameters on Penetration in Shielded Metal Arc Welding under Magnetic Field using Artificial Neural Networks	R.P. Singh, R.C. Gupta S.C. Sarkar	International Journal of Application or Innovation in Engineering & Management 2012.	The defect in welding of mild steel plate (150 mm x 50 mm x 5 mm butt joint) and measuring the output as weld profile by using parameter, arc welding current (90-110 Amp), arc voltage (20-24 V), welding speed (40-80 mm/min), and external magnetic field (0-80 Gauss)
4.	Automatic identification of different types of welding defects in radiographic images	Gang Wang, T. Warren Liao	NDT&E International 35 (2002) ELSEVIER 2002.	Identified the different types welding defects such as lack of fusion, porosity, crack, gas hole etc by using radiographic image processing.
5.	A comparative evaluation of ultrasonic testing of AISI 316L welds made by shielded metal arc welding and gas tungsten arc welding processes	S.M. Tabatabaeipour, F. Honarvar	Journal of Materials Processing Technology ELSEVIER 2010	They use process of ultrasonic testing to measure the comparative analysis of defects in SMAW and GTAW process. defect is measured by the X-ray radiography then the ultrasonic time-of-flight diffraction is applied on specimen 6MHz
6.	Optimization of parameters of submerged arc weld using non-conventional techniques	J. Edwin Raja Dhasa, S. Kumananb	ELSEVIER 2011	The defects in welding process such as deposition of material (weld bead profile), and hardness by using parameters such as of welding current (360-390A), welding speed (400-420 mm/min), arc voltage (25-26V) and electrode stick out (19-25 mm)
7.	Determination of submerge metal arc welding process parameter using Taguchi method and regression analysis	S. Kumanan, J. Edwin Raja Das	Indian journal of engineering and material science. 2007	Measuring the different welding defects in weld bead dimension such as bead width, bead reinforcement, depth of penetration and bead hardness, holes on mild steel plate (500 mm x 50 mm x 6 mm) by using parameter. welding current, arc voltage, welding speed, and electrode stick out

#### Analysis of literature Review



#### 2.2 From Relevant Workshop

Durga Engineering Workshop at wadi near petrol pump, Nagpur. working on all sheet metal works making products

such as DP case, hopper of big rice mill, boxes of sheet metal and using the SMAW process for welding. The thickness of sheet they are using from 20-18 gauge. The

defects arises in welding are incomplete fusion, holes, porosity etc which giving bad appearance of product.

Shree Sitaram Engineering Workshop at bypass road, Ramtek it is a metal fabricating workshop. mainly produce Shutter, Grills, Ladder, Pipe gate, Windows, iron Doors. In joining of sheet due to improper welding parameters the problem of holes are seen in sheet welding because of excess heat generation causes melting of sheet. If sheet are joint with channel sheet melted fast therefore improper welding occur.

Rajesh Engineering Workshop at mandir road, Ramtek manufacturing the product such as Pipe gate, sintering

plate, windows, ladders, collapse gate, iron doors. They are using high voltage SMAW process to join the metals. The defect in weld are holes in pipe, incomplete penetration, incomplete fusion are found

Hannef welding workshop at super market, Ramtek mostly working on manufacturing of metal counters and pan shop. The welding is on angle having more thickness and sheet having less thickness. The sheet melted first due to more heat generation and which is not fuse with angle having more thickness therefore incomplete fusion type of defect is found. Welding thick material the heat generation is more and due to uneven cooling cracks and porosity type of defects are found.



**Fig. 4. Incomplete Fusion**



**Fig. 5. Holes**



**Fig. 6. Incomplete Penetration**

### 3. RESEARCH GAP

After studying above literature review (both journals and workshop), it is found that

1. There is no standard setting of welding parameters (Trial and error method is used)
2. Less work is done to weld mild steel sheets having less thickness
3. Input parameters like electrode angle, welding speed are not considered.
4. The problem of defects like porosity, spatter, wall fusion interface is not discussed with Taguchi and DOE approach.

The different types of defect occur in welding because of improper setting of welding parameter are porosity, incomplete fusions, holes, weld bead geometry, incomplete penetration, crack. These types of defect decrease the strength of product. To improve the strength it is require repairing the defect. The repairing cost is additional to the manufacturing cost of product. Also the defect causing bad appearance of product it decreases the selling price of product. The different parameters affecting the weld quality are welding current, arc voltage, welding speed, electrode angle etc.

### 4. CONCLUSSION

Less work is done to weld mild steel sheets having less thickness (less than 6mm). Input parameter such as electrode angle, welding current, arc voltage and welding speed is mainly affected the welding quality. Taguchi is the best tool of design of experiment to optimize the process. Weld quality is mainly depending on penetration, and fusion of parent material it is affected by welding current, arc voltage and welding speed. If welding current and arc voltage is maximum and welding speed is minimum gives the highest penetration and fusion of material.

### 5. FUTURE SCOPE

By using above literature reviews and identified research gap, one can optimize the SMA welding process to

- Minimize the welding defects lile porosity, incomplete fusion, holes, incomplete penetration and spatter,
- Reduce the repairing cost,
- Reduce wiewlding time
- Maximize the welding surface quality (weld profile) and productivity.

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# Design and Development of an Extruder Assembly to Enhance the Performance of a Plastic 3D Printer

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**Abstract:** The digitization and advancement in technology increase the application of 3D printer for prototyping. The practitioners and researches needs a solution to enhance the performance of 3D printer. To design and develop an extruder assembly for performance enhancement of 3D printer. Identify the different needs from practitioners. Identify different alternatives to satisfy needs. Select the best alternative and develop the model. Validate the design through prototype. Enhance the performance of 3D printer by using extruder assembly. The assembly is easy to mount and operate. The 3D printer can be used as chocolate printer by mounting developed extruder assembly. The solution is cost effective with respect to functionality. Increase the functionality of 3D printer and motivates practitioners to take new challenges.

**Keywords:** Brainstorming, Delphi method, plastic 3D printer, Ansys16.0

## 1. INTRODUCTION

The concept of 3D printing started with stereo-lithography. Charles Hull (Hull, 1986) filed a patent for stereo-lithography. The process of stereo-lithography was started by using the principles of additive manufacturing. Eventually over the years, stereo-lithography was developed in different types and one of its forms is 3D printing. In, recent years 3D printers have become cheaper to produce; several models are now available for sale, as well as designs for products. Experts predict 3D printers will be common in homes in coming years (Campbell et al., 2011; Rayna and Striukova, 2016; Shewbridge et al., 2014). 3D printers are not only used to print plastic materials but also to print food like chocolate etc.(Godoi et al., 2016; Li et al., 2014; Sun et al., 2015). The major challenge is separate 3D printers are needed to print chocolate and plastic. In today's era of technology plastic 3D printers are widely used for prototyping, which are not useful for chocolate printing. Therefore, small scale chocolate printing is still a dream for many, who own plastic extrusion 3D printers. There is need to give solution to overcome the difficulty of buying a new machine altogether.

## 2. PROBLEM SELECTION

In this section of paper, different projects were identified related to 3D printing as shown in Table 1.

**TABLE 1: List of projects related to 3D printer**

Project Code	Project description
P1	Select most efficient plastic for 3D printing (Abs, Pla, PLC)
P2	Design and develop extruder assembly to print chocolate.

P3	Identify different factors to reduce print waste.
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The Delphi method (Dalkey and Helmer, 1963; Linstone et al., 1975; Okoli and Pawlowski, 2004) was used to select most critical project. The panel of 16 experts was selected to perform Delphi method. The detail of experts is as shown in Table 2. In first round of Delphi method the different projects were discussed and finalized the criteria to rank the projects along with the weights of each criterion. In the second round of Delphi method the expert's opinion were collected and analyzed. The result of Delphi method is as shown in Table 3. The Delphi method suggested design and development extruder assembly to print chocolate is most critical project.

**TABLE 2: Details of expert panel**

Sr. No.	Expert	No. of experts (16)	Percentage (%)
1	Top Management	3	18.75
2	Middle-level Managers	7	43.75
3	Lower level Managers	6	37.50

**TABLE 3: Project Selection Matrix**

Sr. No.	Project	Criteria (Weight)			Total
		Cost Saving (0.5)	Customer satisfaction (0.3)	Profit (0.2)	
1	P1	5	5	4	4.8
2	P2	7	11	8	8.4
3	P3	4	4	5	4.2



### 3. RESEARCH METHODOLOGY

In this section the methodology was developed and as shown in figure 1. The various problems are identified based on literature survey and expert discussion. The Delphi method was used to identify critical problem. In next part of methodology model was developed and validate by performance testing.

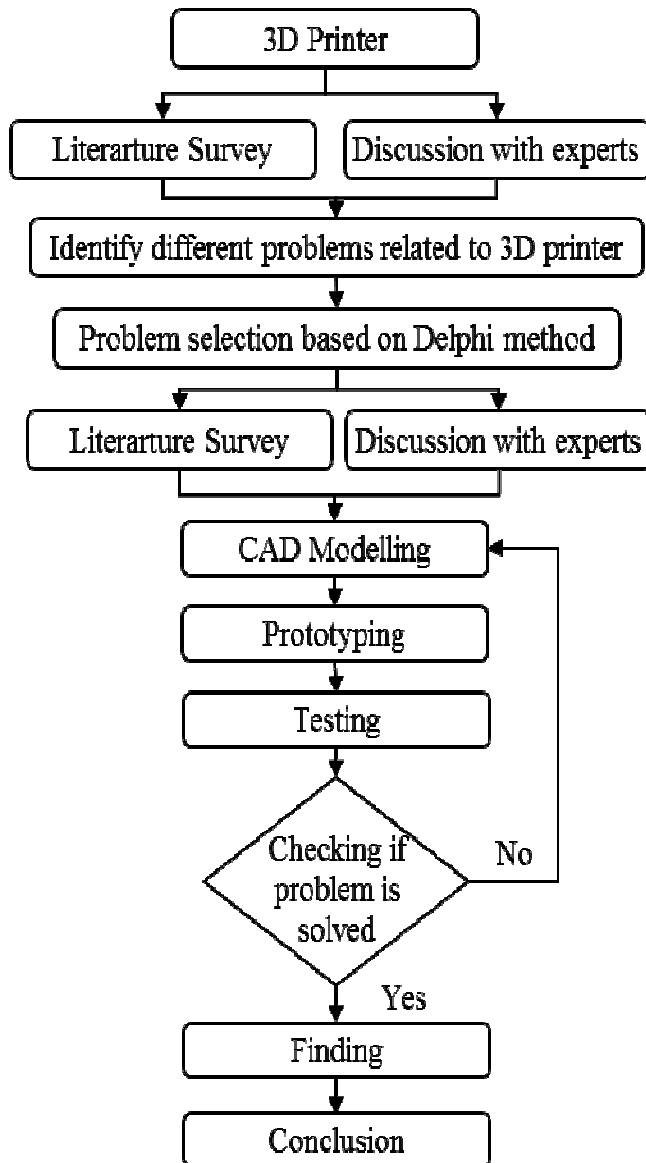


Fig. 1. Research Methodology

### 4. MODELING THE DESIGN

Modeling is the process of creating, developing and communicating ideas to give solution for problem. It includes the process of constructing the idea, innovating the concept, developing the process, and bringing the concept into reality. Idea generation is a vital part of the design procedure. The main focus of idea is to make the

expensive dreams of chocolate printing affordable. According to our research, many companies manufacture separate 3D printers to print chocolate. The motivation is to design and develop the assembly which can be easily mounted on an existing 3D printer and print chocolate. The design of assembly should be compact in size and light in weight. The design made by simple and easily available components, making it affordable. After design of the assembly, it is tested by prototype for validation of design.

#### 4.1 Concept Design

Once idea generation is done, the next important step is concept design. This method mainly includes the generation of shape to the generated idea. In this step we used the Autodesk Inventor software for concept design. We generated two concepts (Figure 2) and further improvisations are done based on same idea.

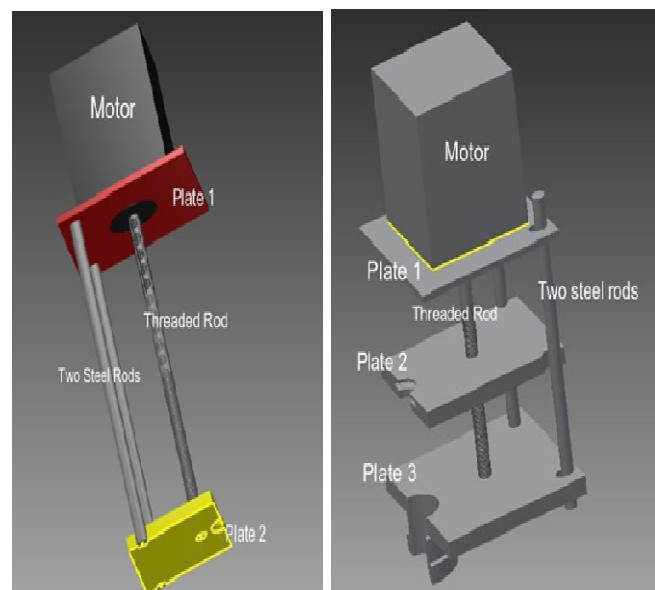


Fig. 2. Concept Design

The assembly consists of threaded rod and nut mechanism. The function of threaded rod is too rotate for producing linear motion of the nut. The threaded rod is coupled to the motor shaft using a coupler. The nut on plate (2) is mounted in a through hole from which the shaft is passing in (Figure 2). Therefore the direction of rotation of a nut is same as motor shaft. A nut and piston of a syringe are mounted on plate 2. To hold the syringe body a special provision is given on plate 3. As the nut mounted on plate 2 rotated by means of motor shaft the plate starts rotating along with the nut. Since pressure needs to be exerted on a piston to move it through the syringe body and extrude the material the rotational motion of plate 2 is constrained by linear ball bearing (LM8UU). With the help of bearings the linear motion of plate 2 is achieved subsequently piston started reciprocating through syringe body. This reciprocating

motion is controlled by the stepper motor due to which extrusion is controlled. The steps of stepper motors are controlled by the arduino micro-controller of the default 3D printer. As the motor starts the threaded shaft which is coupled with motor shaft starts rotating. The fixed nut also starts rotating along with the plate. The linear bearing is provided to constrain the rotational motion of the plate (2). Due to constrain rotational motion of plate is converted in linear motion. This linear motion of plate (2) is used to create reciprocating action of a piston inside the syringe body, which is used for extrusion of chocolate.

#### 4.2 Chocolate Extruder

The assembly uses a syringe type extruder to print the chocolate. While printing chocolate, various factors should be taken in account for smooth layering. Chocolate melts at very low temperatures as compared to plastic. The melting temperature plastic filament is usually in between 210⁰-

250⁰ and that of plastic is 29⁰-35⁰. Plastic also takes time to solidify after printing. The perfect extrusion of chocolate from the assembly has been observed when Bourneville mixed with Hershey's Chocolate syrup is used. For chocolates other than Bourneville, we made some changes in the assembly. The syringe in the assembly is covered with Kapton tape and a copper wire. When current is passed through the copper wire, heat is generated. This increases the temperature of the coil and is measured by a temperature sensor. The temperature in the coil is maintained to the melting point of the chocolate. This results in the successful extrusion of any chocolate through the extruder. During the experiments, we observed that if the surrounding temperature is low (below 10⁰), then the setting time of the chocolate on the printing bed is reduced. This is concluded through experiments performed during day and midnight. The part list of extruder assembly is as shown in Table 4.

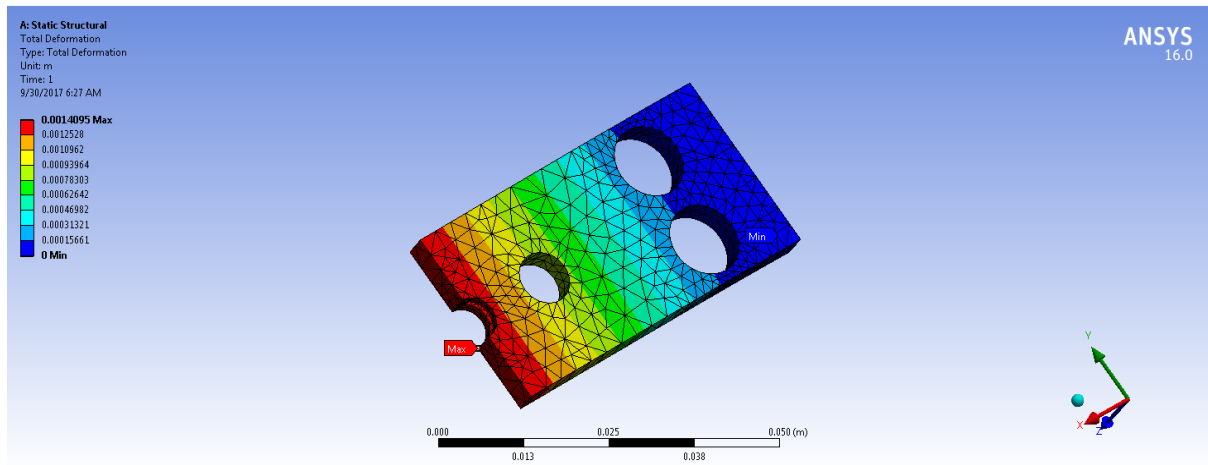
**TABLE 4: part list of extruder assembly**

Sr. No.	Part	Function	Specifications	Quantity
1	Stepper Motor	To control the feed rate of syringe extruder	Nema 17, 1.7° step.	1
2	Plate 1	To hold the stepper motor	Material Plastic, 3D printed	1
3	Steel Rods	To support linear bearings	M8, Steel, both ends threaded	2
4	Coupler	Coupling between motor shaft and threaded shaft	5mm-8mm, Aluminium	1
5	Linear Bearings	To support the plate to move in reciprocating linear motion	LM8uu Linear ball bearings	2
6	Plate 2	To press the piston of syringe to extrude the material	Material Plastic, 3D printed	1
7	Plate 3	To support the syringe body	Material Plastic, 3D printed	1
8	Threaded Rod	To convert rotary motion to linear motion.	M8x1	1
9	Syringe	Contains extruding material(Chocolate)	10mL syringe.	1
10	Nut	Fasting	M8	6

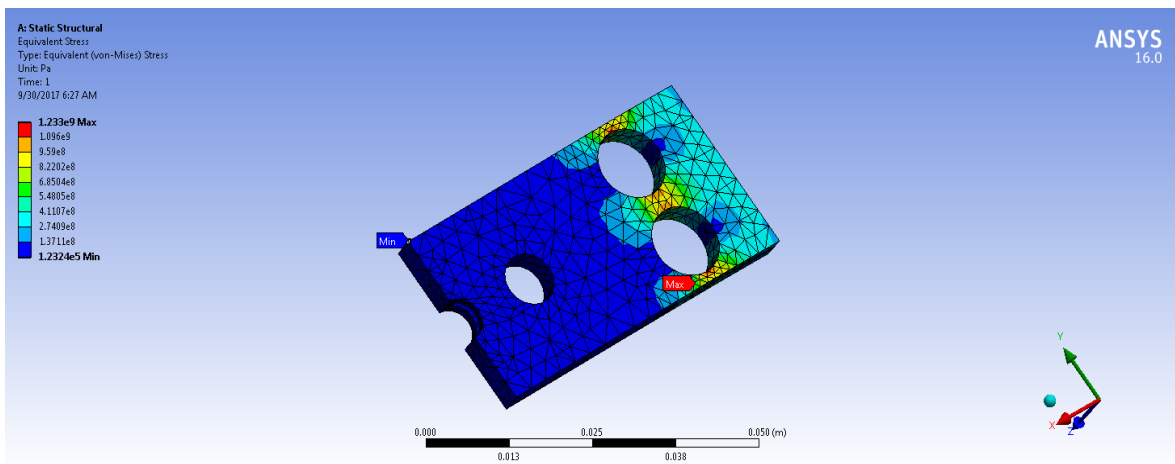
#### 5. ANALYSIS

The static stress and deformation analysis of the two plates is done on the Ansys 16.0. The stress induced in plate 2 is majorly due to the lag occurring in the linear motion between a shaft and bearing side. If the bearing are not moving simultaneously with the nut attached on the plate 2 then it shows the bending moment. In the analysis the point load is applied near the shaft side to study the maximum and minimum bending moment. The fixed support was assumed based on the back side of the plate near the two bearing holes. The static stress analysis is studied for plate 3, as the plate two pushes the piston in downward direction, some force exerts on the plate 3. The nuts are attached to

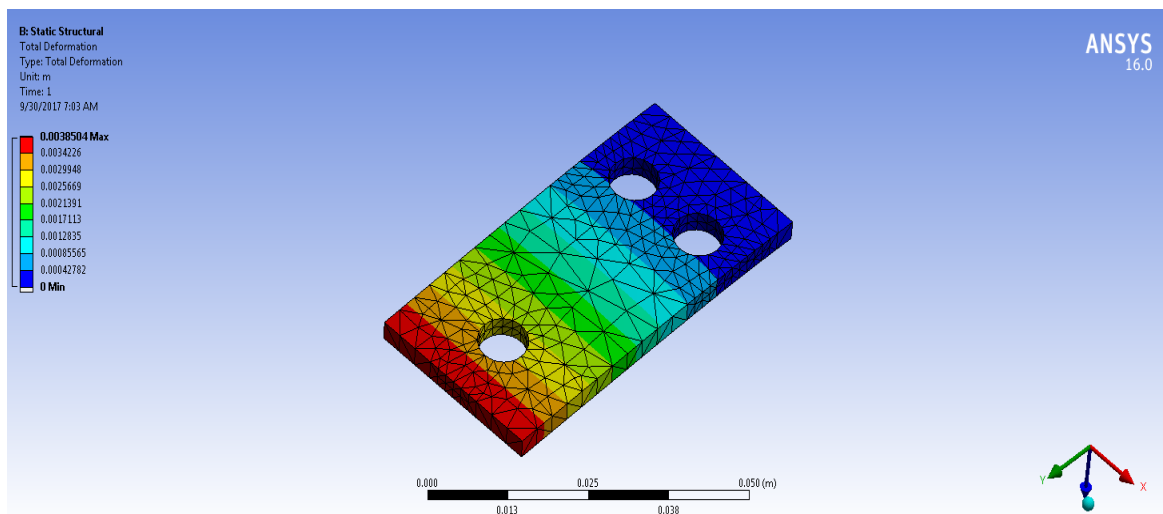
rear through holes of the plate to hold the steel rods. This part of the plate acts as a fixed support as no force is acting in this area. Due to press force on piston the plate tends to bend in downward direction therefore the rough idea of maximum and minimum stress acting on the plate is obtained by the Static analysis. The press force is assumed as a point force acting near to through hole. This Analysis gives the rough idea about the feasibility of the assembly. The Figure 3 and Figure 4 shows the bending and stress analysis for plate 2. Similarly, Figure 5 and Figure 6 shows the bending and stress analysis for plate 3. The analysis shows that the stress and bending induced in plates are under control conditions hence the design is safe.



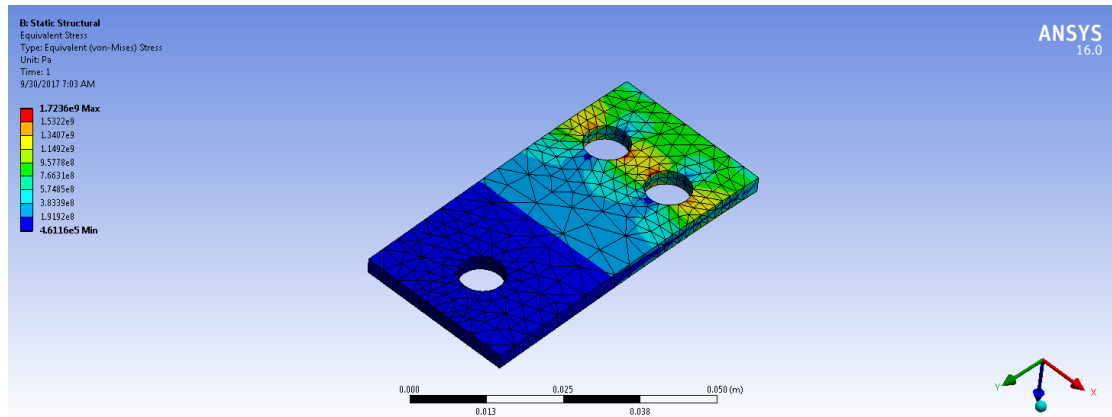
**Fig. 3. Bending (Total deformation) analysis for Plate 2**



**Fig. 4. Stress Analysis for Plate 2**



**Fig. 5. Bending (Total Deformation) analysis for Plate 3**

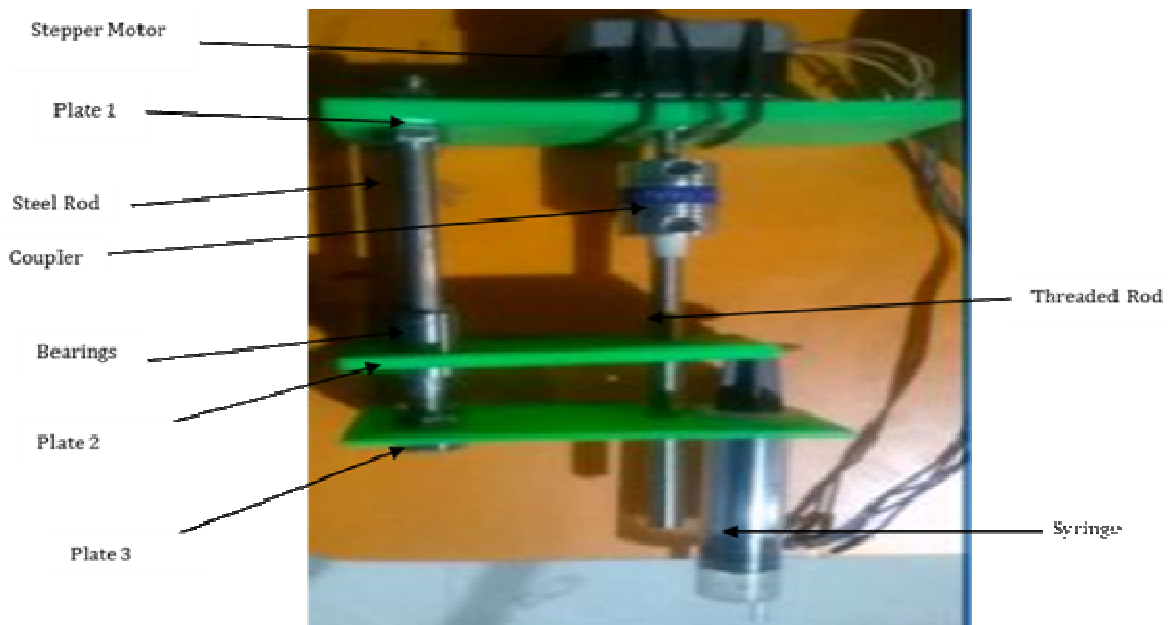


**Fig. 6. Stress Analysis for Plate 3**

## 6. PROTOTYPING FOR TESTING

This is a very important step as it gives realistic scenario of 3D model. We ordered the parts required for assembly (Coupler, Bearings and shaft) from a commercial metal market in Delhi. During assembly problems were faced in attachment of bearing on steel rod. Bearing were not able

move simultaneous with the Nut in the plate 2 which was creating bending movement in the plate. The issue was solved by reducing the diameter of the rods by 200-300 microns by polish paper. The issue was eliminated and assembly was built successfully and was ready for testing (Figure 7).



**Fig. 7. Prototype for testing**

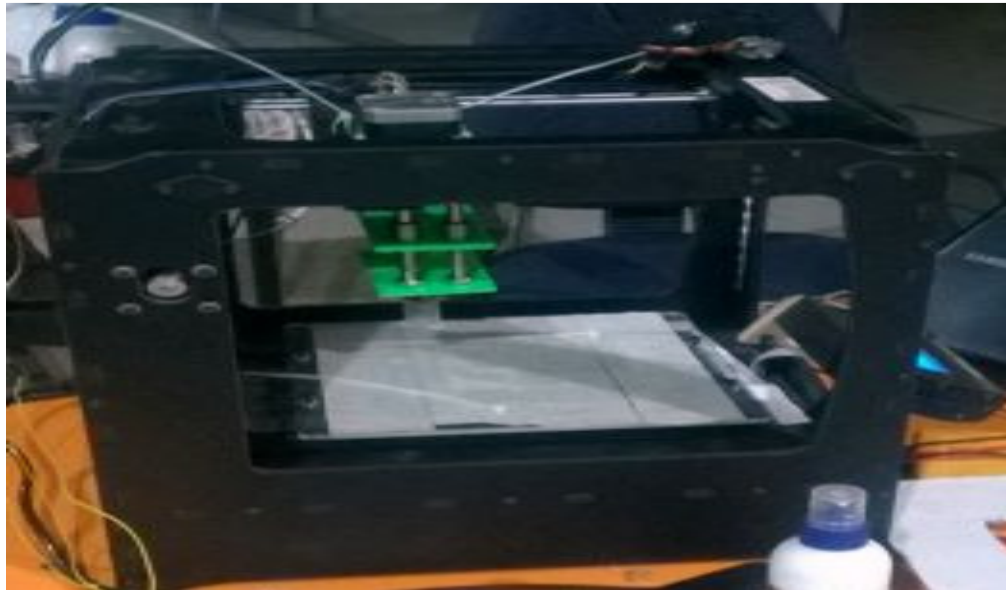
## 7. TESTING FOR VALIDATION

The testing is essential aspect of design. It used to validate the design. The installation of assembly on 3D printer was major challenge. The Figure 8 shows the setup for prototype testing. At the time of installation and testing of assembly the following issues were faced.

- Fixing the assembly on the moving axes of the 3D printer.
- Changes in the firmware of Arduino Microcontroller. (Firmware: Code which converts .stl format to G-code).
- Selection of chocolate mixture.

The rubber fasteners were used to fix the assembly on moving axes of 3D printer. The few changes are made in the firmware. The few experiments were performed to finalize the desired changes. The proposed changes are reduction in steps per mm of extruder from 3700 steps/mm to 75 steps/mm in the firmware, reduction in temperature

from 190°C to 28°C, and preheats temperatures to 28°C and reduction in feed rate of extruding chocolate to 4-5mm/sec. The Selection of chocolate is one of the important factor for assembly testing. The various chocolates were tried with different combinations of mixtures, as shown in Table 5. The best chocolate was chosen solely from observations.



**Fig. 8. Setup for Prototype Testing**

**TABLE 5: different combinations of mixtures**

Chocolate	Problem	Proposed Action Plan
Cadbury Dairymilk + Water + Heat( 28°C)	Less Denser, Did not solidify	Change the liquid
Cadbury Dairymilk + Milk + Heat( 28°C)	Less Denser, Did not solidify	Change the Chocolate(Dairymilk to crunchy)
Munch + KitKat +Milk + Heat( 28°C)	Not able to extrude + Very Thick.	Change the chocolate and addition of chocolate paste.
Bourneville + Hershey's Chocolate Paste	Thick, Not able to extrude from nozzle	Heat addition
Bourneville + Hershey's Chocolate Paste + Milk + Heat( 28°C)	Accepted.	-

## 8. RESULTS

The analysis shows that the maximum deformation of plate 2 and plate 3 are 1.4mm and 3.8mm respectively. The result shows that the design is safe and capable of handling induced stress. The experiments have shown minimum temperature required for extrusion as 28°C. The obtained final combination of mixture for good result is as Bourneville, Hershey's Chocolate Paste, Milk and Heat (28°C).

## 9. CONCLUSION

This paper demonstrates how to design and mount simple syringe piston extruder assembly on plastic 3D printer. The developed prototype is very cost effective, easy to manufacture and easy to use. It will print various 3D chocolate shapes which can be used to attract customers in various cake and chocolate shops. The assembly will be able to reduce the need of buying a separate chocolate printer for small scale as well as for household prototyping.

The study concluded, the setting time of chocolate after extrusion depends on the atmospheric temperature and the rate of extrusion depends on type of chocolates used and heat.

## 10. FUTURE SCOPE

In the further study, the manual filling of chocolate in syringe can be convert to automatic filler and optimization of mixture and temperature. Design and development of syringe for better results.

## 11. ACKNOWLEDGEMENT

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# Multi Objective Optimization of Process Parameters of Dry EDM using Grey Relational Analysis

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**Abstract:** This article focuses on an approach based on the Taguchi method with grey relational analysis for optimizing the process parameters of Dry Electric Discharge Machine. This paper presents an effective approach to optimize process parameters for dry electro discharge machining. Dry EDM is extensively used in tool and die industries. Precision and intricate machining are the strengths of this machining process. While machining time and surface quality still remains as major challenges. The main objective of this study is to obtain higher material removal rate (MRR), lower tool wear rate (TWR) and lower surface roughness (SR). Current, pulse on time and pressure of dielectric medium are the tree process parameters taken each at various levels. Since the process has multiple performance characteristics, the grey relational analysis is used. The grey relational grade normalizes the contradicting performance indices. From eight experiments based on the orthogonal array of L18 the best combination of parameters were found. Compared with Taguchi's method the proposed method is more scientific. The experimental results confirm that the proposed method in this study effectively improves the machining performance of Dry EDM process.

**Keywords:** Dry EDM, Taguchi, Grey Relational Analysis

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## 1. INTRODUCTION

The proposition of Grey theory occurring in the 1990 to 1999 time period resulted in the uses of Grey theory to each field, and the development is still going on. The major advantage of Grey theory is that it can handle both incomplete information and unclear problems very precisely. It serves as an analysis tool especially in cases when there is no enough data. It was recognized that the Grey relational analysis in Grey theory had been largely applied to project selection, prediction analysis, performance evaluation, and factor effect evaluation due to the Grey relational analysis software development.

In electrical discharge machining (EDM), it is important to select machining parameters for achieving optimal machining performance. Usually, the desired machining parameters are determined based on experience or on handbook values. However, this does not ensure that the selected machining parameters result in optimal or near optimal machining performance for that particular electrical discharge machine and environment. It has been shown that the grey-based Taguchi method can optimize the multi-response processes through the settings of the process parameters; but, in this paper, the grey relational analysis is not used for calculating the S/N ratio. This is because grey relational analysis based on the grey system theory is used for solving the complicated interrelationships among the multiple responses. A grey relational grade is then obtained for analyzing the relational degree of the multiple responses.

To optimize the process based on the experimental data, the traditional statistical regression requires a large amount of data that causes the difficulty in treating the typical normal distribution of data and the lack of variant factors. In the grey system theory, the grey relational analysis is a measurement method to analyze the relationship between sequences using less data and multi-factor, which is considered more advantageous to the statistical regression analysis. The grey relational analysis based Taguchi method is introduced. Then, the experimental results when using grey relational analysis based Taguchi method to optimise the EDM process with minimum electrode wear ratio, surface roughness and maximum material removal rate, are given. Finally, the paper concludes with the results and discussions.

N. Pragadhish and M. Pradeep Kumar worked on dry Electro Discharge Machining for drilling purpose. Taguchi (L27) based design of experiment was adopted. Current, pulse on time, pressure, tool rotation used as process parameters to study surface morphology of the workpiece. This multi objective optimization was done with the help of Gray Relation Analysis. ANNOVA results shows current and pressure were the most significant factors.

S. Jadhav was worked on multi objective optimization of performance (BSFC) and emission ( $\text{NO}_x$ ) characteristics for C.I. Engine operated on Mangifera Indica Methyl Ester using Taguchi Grey Relation Analysis. The researcher used L25 orthogonal array to design the experiments and Grey

Relation Analysis to optimize level of process parameters to control BSFC and NOX.

Jong Hyuk Jung and Won Tae Kwon made attempt to find the optimal machining conditions under which the micro-hole can be formed to a minimum diameter and a maximum aspect ratio. The Taguchi method was used to determine the relations between machining parameters and process characteristics. It was found that electrode wear and the entrance and exit clearances had a significant effect on the diameter of the micro-hole when the diameter of the electrode was identical. Grey relational analysis was used to determine the optimal machining parameters, among which the input voltage and the capacitance were found to be the most significant.

## 2. DESIGN OF EXPERIMENTS

Electrical discharge machining removes material from a workpiece by an electrical spark erosion process. Common methods of evaluating machining performance in the EDM operation are based on the following performance characteristics: material removal rate; surface roughness; and electrode wear ratio. Material removal rate, surface roughness, and electrode wear ratio are correlated with machining parameters such as pulse on time, duty factor,

discharge current, etc. Proper selection of the machining parameters can result in a higher material removal rate, better surface finish, and lower electrode wear ratio.

### 2.1. Machining Parameter Selection and Orthogonal Array Table

The selection of parameters and their levels are decided from preliminary experiments. During preliminary experiments it is found that optimum range of current between 14 ampto 18 amp. As surface roughness is a response variable in this study and very poor surface finish was obtained for 18 amp current. Therefore only two levels of current are selected between 14 amp and 18 amp whereas three levels of pulse on time and dielectric pressure are selected as per preliminary experiments. The final experiments are performed with same values of pulse on time used in preliminary experiments. The preliminary experiments are performed with pressure of 0.5 bar, 1 bar and 1.5 bar and final experiments are performed with higher dielectric pressure. The final experiments are performed with dielectric pressure of 1 bar, 1.5 bar and 2 bar. In case of dielectric, increased pressure is used to improve response variables. Process parameters and their levels for final experiments are shown in Table I.

**TABLE I: Process Parameters and Their Levels for Final Experiments**

Process Parameters	Levels		
	1	2	3
Current, I (amp.)	15	16	-
Pulse on time, POT ( $\mu$ s)	50	100	200
Pressure, P (bar)	1	1.5	2

Orthogonal array for experimental work with two levels of current, three levels of pulse on time and dielectric pressure respectively are shown in Table II.

**TABLE II: Experimental  $L_{18}(2^1 \times 3^7)$  Orthogonal Array**

Experiment No.	Current (amp)	Pulse on time ( $\mu$ s)	Dielectric pressure (bar)
1	15	50	1.0
2	15	50	1.5
3	15	50	2.0
4	15	100	1.0
5	15	100	1.5
6	15	100	2.0
7	15	200	1.0
8	15	200	1.5
9	15	200	2.0
10	16	50	1.0
11	16	50	1.5



Experiment No.	Current (amp)	Pulse on time ( $\mu$ s)	Dielectric pressure (bar)
12	16	50	2.0
13	16	100	1.0
14	16	100	1.5
15	16	100	2.0
16	16	200	1.0
17	16	200	1.5
18	16	200	2.0

### 3. RESULT AND ANALYSIS OF EXPERIMENTS

The experimental work was conducted on EDM for drilling purpose. Taguchi based design of experiment was adopted to design the experiment. Experimental results for material removal rate, tool wear rate and surface roughness by varying current, pulse on time and dielectric pressure as per  $L_{18}$  orthogonal array are shown in Table III.

**TABLE III: Experimental Results**

Experiment number	Process parameters			Response variables		
	Current(amp)	POT( $\mu$ s)	Pressure (bar)	MRR (gm/min)	TWR (gm/min)	SR ( $\mu$ mRa)
1	15	50	1	0.0392	0.0000	3.2
2	15	50	1.5	0.0205	0.0000	4.2
3	15	50	2	0.0270	0.0000	3.6
4	15	100	1	0.0588	0.0000	4.6
5	15	100	1.5	0.0632	0.0000	4
6	15	100	2	0.0698	0.0000	3.6
7	15	200	1	0.0542	-0.0005	4.6
8	15	200	1.5	0.0623	-0.0011	3.6
9	15	200	2	0.0231	-0.0017	3.8
10	16	50	1	0.0484	0.0012	4.6
11	16	50	1.5	0.0335	0.0011	4.8
12	16	50	2	0.0718	0.0012	5.2
13	16	100	1	0.0757	0.0013	3.8
14	16	100	1.5	0.1080	0.0022	4.4
15	16	100	2	0.1092	0.0022	4.6
16	16	200	1	0.0249	0.0000	4.2
17	16	200	1.5	0.0209	0.0000	4.4
18	16	200	2	0.0408	0.0000	4.4

#### 3.1. Multi-objective optimization using Grey Relational Analysis (GRA)

The Grey Relational Analysis (GRA) associated with the Taguchi method represents a rather new approach to optimization. The grey theory is based on the random uncertainty of small samples which developed into an evaluation technique to solve certain problems of system

that are complex and having incomplete information. A system for which the relevant information is completely known is a 'white' system, while a system for which the relevant information is completely unknown is a 'black' system. Any system between these limits is a 'grey' system having poor and limited information [12]. Grey Relational Analysis a normalization evaluation technique is extended to solve the complicated multi-performance

characteristicsoptimization effectively.The grey relational analysis based on the grey system theory which has several advantages: It involves simple calculations and requires a small number of samples; a normal distribution of samples is not needed, the qualified outcomes from the grey relational grade do not result in contradictory conclusions from the quantitative analysis, the grey relational grade

model is a transfer functional model that is effective in dealing with discrete data. Since as per the grey theorythree response variables are selected for the GRA such as material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR).Grey relational analysis is given in Table IV.

**TABLE IV: Grey Relational Analysis**

Experiment Number	MRR	TWR	SR	MRR (GRG)	TWR (GRG)	SR (GRG)	MRR (GRC)	TWR (GRC)	SR (GRC)	GRG	Rank
1	0.0392	0.0000	3.2	0.2110	0.5581	1	0.5590	0.6935	1.0000	0.7508	3
2	0.0205	0.0000	4.2	0.0000	0.5581	0.5	0.5000	0.6935	0.6667	0.6201	14
3	0.0270	0.0000	3.6	0.0740	0.5581	0.8	0.5192	0.6935	0.8333	0.6820	9
4	0.0588	0.0000	4.6	0.4324	0.5581	0.3	0.6379	0.6935	0.5882	0.6399	11
5	0.0632	0.0000	4	0.4817	0.5581	0.6	0.6586	0.6935	0.7143	0.6888	7
6	0.0698	0.0000	3.6	0.5565	0.5581	0.8	0.6928	0.6935	0.8333	0.7399	4
7	0.0542	-0.0005	4.6	0.3800	0.6965	0.3	0.6173	0.7672	0.5882	0.6576	10
8	0.0623	-0.0011	3.6	0.4715	0.8475	0.8	0.6542	0.8677	0.8333	0.7851	1
9	0.0231	-0.0017	3.8	0.0292	1.0000	0.7	0.5074	1.0000	0.7692	0.7589	2
10	0.0484	0.0012	4.6	0.3152	0.2486	0.3	0.5936	0.5710	0.5882	0.5843	17
11	0.0335	0.0011	4.8	0.1468	0.2728	0.2	0.5396	0.5790	0.5556	0.5580	18
12	0.0718	0.0012	5.2	0.5784	0.2523	0	0.7034	0.5722	0.5000	0.5919	16
13	0.0757	0.0013	3.8	0.6223	0.2357	0.7	0.7258	0.5668	0.7692	0.6873	8
14	0.1080	0.0022	4.4	0.9867	0.0060	0.4	0.9869	0.5015	0.6250	0.7045	5
15	0.1092	0.0022	4.6	1.0000	0.0000	0.3	1.0000	0.5000	0.5882	0.6961	6
16	0.0249	0.0000	4.2	0.0497	0.5581	0.5	0.5128	0.6935	0.6667	0.6243	13
17	0.0209	0.0000	4.4	0.0054	0.5581	0.4	0.5014	0.6935	0.6250	0.6066	15
18	0.0408	0.0000	4.4	0.2294	0.5581	0.4	0.5648	0.6935	0.6250	0.6278	12

The grey relational generation is calculated as per the equation (i) and equation (ii) [26-27].

Larger the better

$$X_{ij} = \frac{Y_{ij} - \min_i Y_{ij}}{\max_i Y_{ij} - \min_i Y_{ij}} \quad \dots(i)$$

Smaller the better

$$X_{ij} = \frac{\max_i Y_{ij} - Y_{ij}}{\max_i Y_{ij} - \min_i Y_{ij}} \quad \dots(ii)$$

Where,

$Y_{ij}$  is the  $i^{th}$  performance characteristic in the  $j^{th}$  experiment ( $i=1, 2, 3, \dots, 27; k=1, 2, 3$ )

$\max_i Y_{ij}$  and  $\min_i Y_{ij}$  are the maximum and minimum values of  $i^{th}$  performance characteristics for alternate  $j$  respectively.

In the grey relational analysis, the grey relational grade is used to show the relationship among the series. Let  $(X, \Gamma)$  be a grey relational space,  $X$  stand for the collection of grey relational factors,  $x_i$  be the compared series, and  $x_0$  be the reference series [19]. The grey relational grade is

formulated by using equation (iii) and equation (iv) [13, 18].

$$x_i = (x_i(1), x_i(2), \dots, x_i(n)), \quad \dots(iii) \\ x_i \in X, i = 1, 2, \dots, m$$

$$x_o = (x_o(1), x_o(2), \dots, x_o(n)), \quad x_o \in X_o \quad \dots(iv)$$

The grey relational coefficient (GRC) is calculated as per the equation (v) [21, 26],

$$\gamma(x_o(k)) = \frac{\Delta \min + \zeta \Delta \max}{\Delta_{oi}(k) + \zeta \Delta \max} \quad \dots(v)$$

Where,

$$i = 1, 2, \dots, 27; k = 1, 2, 3$$

$$\Delta \min = \min_i \min_j \|x_o(k) - x_i(k)\|$$

$$\Delta \max = \max_i \max_j \|x_o(k) - x_i(k)\|$$

The Grey Relational Grade (GRG) is obtained as per the equation (VI) [18],

$$\gamma(x_o, x_i) = \frac{1}{m} \sum_{k=1}^m \gamma(x_o(k), x_i(k)) \quad \dots(vi)$$

Grey relational grade has calculated as per equation 2.6 and arranged them in descending order. That descending order has named as rank and rank 1 indicates best condition and rank 18 indicates worst condition. The selected experiments numbers are 8 (rank 1) and 9 (rank 2) for best condition. Best condition as per GRA rank shows in Table V.

**TABLE V: Best Condition as per GRA Rank**

Level	Expt. No.	Current	POT	Pressure	MRR	TWR	SR
1	8	15	200	1.5	0.0623	0.0011	3.6
2	9	15	200	2	0.0231	0.0017	3.8

The grey relation analysis shows worst results from experimental results. Experiments numbers 11 (rank 18) and 10 (rank 17) for worst condition. The worst condition as per GRA rank shows in Table VI.

**TABLE VI: Worst Condition as per GRA Rank**

Level	Expt. No.	Current	POT	Pressure	MRR	TWR	SR
1	11	16	50	1.5	0.0335	0.0012	4.8
2	10	16	50	1	0.0484	0.0011	4.6

### 3.2 Determination of optimal parameters

The GRG calculated for each sequence is taken as response for further analysis. The larger the better quality characteristic has been used for analysis, since it indicates the better performance of the process. The GRG obtained is analysed using ANOVA and analysis of mean plots. ANOVA is used to identify the statistical significance of individual parameter on particular response. The response table of Taguchi method was employed here to calculate the average GRG for each factor level.

#### 3.2.1. Response table for grey relational grade

Response table for grey relational grade shows in Table VII. A response table gives ranks of parameters and current stands for first rank in grey relational grade.

**TABLE VII: Mean Response Table for Grey Relational Grade**

Level	Current (A)	POT (μs)	Pressure (bar)
1	-3.093	-4.042	-3.671
2	-4.024	-3.197	-3.657
3		-3.436	-3.347
Max – Min	0.931	0.846	0.324
Rank	1	2	3

#### 3.2.2. Analysis of Variance for grey relational grade

ANOVA for grey relational grade is shown in Table VIII. ANOVA results shows that current is the most significant parameter for grey relational grade.

**TABLE VIII: ANOVA for Grey Relational Grade**

Source	DF	SS	MS	F	P
Current (amp)	1	0.022919	0.022919	7.85	0.016
POT (μs)	2	0.012238	0.006119	2.10	0.166
Pressure (bar)	2	0.002298	0.001149	0.39	0.683
Error	12	0.035027	0.002919		
Total	17	0.072482			

S = 0.0540269 R-Sq = 51.68% R-Sq(adj) = 31.54%

#### 3.2.3. Multiple performance optimized condition using GRA

Main effects plot for Sound to Noise (SN) ratio of Grey Relational Grade is shown in Figure 4.11. From this plot optimum condition of parameter is found also known as multi objective optimization of parameters. Main effects plot for SN ratio gives best and worst conditions which are shown in Figure 4.11. Validation experiments are

performed for best and worst condition using main effects plot for SN ratio which are explained in next section.

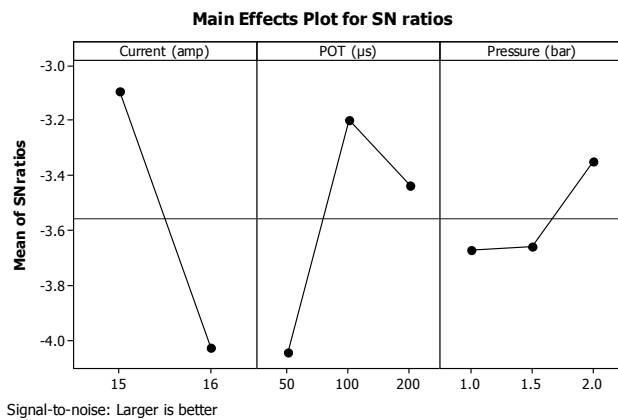


Fig. 1. Main Effects Plot for SN Ratio for GRG

TABLE IX: Best and Worst Conditions using Main Effects Plot of SN Ratio of GRR

Level	Current	POT	Pressure
Best	15	100	2
Worst	16	50	1

#### 4. CONCLUSIONS

The paper presented the optimization of the dry electro discharge machining by the grey relational analysis method. The analysis of the multiple performance characteristics has been performed by grey relational grade. As a result, the response variables are Material Removal Rate (MRR), Tool Wear Rate (TWR) and surface finish can be improved through this method. The effectiveness of this approach is verified by experiment and analysis of variance. As per grey relational grade, best condition for dry electro discharge machining at the level of 8th experimental run (15 amp, 200 μs, 1.5 bar) and worst condition at 11th experimental run (16 amp, 50 μs, 1.5 bar).

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# Review on the Current Applications of Shape Memory Alloys and their Future Scope

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**Abstract:** This paper discusses the current applications of Shape Memory Alloys with regard to their use in the biomedical applications and their application as mechanical actuators. The paper elaborates on the current uses of Shape Memory Alloys in the aforementioned areas and helps gain a deeper understanding of the importance of Shape Memory Alloys as well as their future prospects in the respective fields through exploration of the developments in their applications and research thus far.

**Keywords:** Shape Memory Alloys, Mini Actuators, Biomedical Materials

## 1. INTRODUCTION

Shape Memory Alloys or SMAs are, as the name suggests, alloys that can remember shapes. Due to their nature and ability to remember shapes, they have been seminal in the field of science as well as engineering being typically used as actuators due to their ability to change/vary their stiffness, hardness, toughness, position, natural frequency, and many other mechanical properties. They have brought on an advent in technology that will continue to grow due to the great versatility offered by these alloys (Lin, 2008).

Moreover, the SMA materials exhibit this property by undergoing phase change during heating and cooling cycles. They undergo Martensitic transformation at lower temperature and an Austenitic transformation at elevated temperatures. The Martensitic transformation start temperature is denoted by  $M^S$  and completion of the transformation is indicated by the temperature  $M^F$ . Similarly, Austenite start and finish temperatures are denoted by  $A^S$  and  $A^F$  respectively (Nespoli, Besseghini, Pittaccio, Villa, & Viscuso, 2010). This transformation of the microstructure is the reason for the “memory effect” (TAMU Smart Labs, 2007).

Although the first commercial applications and discovery of the popular SMA NiTiNOL only took place in 1954 in the Naval Ordnance Laboratory, the superelasticity and the shape memory phenomenon ensured that research about commercially viable SMA products began almost immediately afterwards through investigation by means of studying heat treatment, microstructure and composition. The first commercial application was in the case of pipes in the F-14 jets and the pipes were called “Cryofit” (Kumar & Lagoudas, 2008).

In the last decade or so, their versatility and unique properties have seen them garner even more research

interest from the scientific community in fields such as Biomedicine, air conditioning valves, electronic cable connectors, thermo-electric actuators, valves and even civil structures (Song, Ma, & Li, 2008). The rest of this paper concentrates on giving details about the various applications of SMAs and is organized as follows: Section 2 concentrates on the the applications of SMAs as actuators, Section 3 concentrates on the biomedical applications of SMAs while Section 4 talks about the future prospects of the SMAs in the actuator and biomedical fields and Section 5 serves to conclude and summarize the findings of the former sections.

## 2. SHAPE MEMORY ALLOYS – LINEAR MINIATURE ACTUATORS

The whole point of miniaturization is to yield high mechanical performance in a limited space, and in order to do so, the component should be compact and light (Nespoli, Besseghini, Pittaccio, Villa, & Viscuso, 2010). The graph below shows the reason behind the suitability of SMA actuators as a function of power-to-weight ratio plotted against the weight of the actuator:

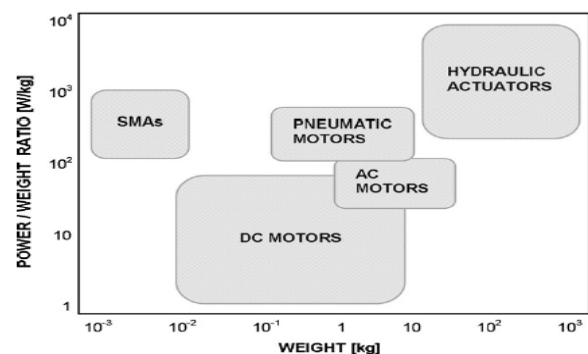


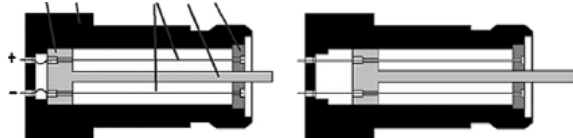
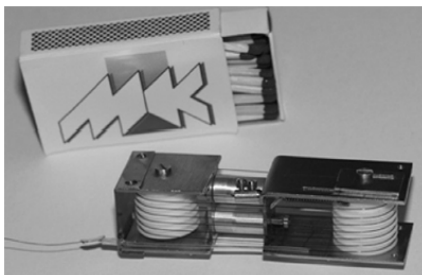
Fig. 1. Power-to-weight ratio vs weight (Ikuta, 1990), (Marvoldis, 2002) of different actuator technologies.

Advantages to using SMA materials as actuators are: simplicity of the mechanism, cleanliness, low driving voltage, remotability, silent actuation (Ikuta, 1990). However, they do suffer from certain shortcomings: low driving efficiency (<10%), strong relationship between strain operation range and fatigue life (Ikuta, 1990), low response speed and non-linear behavior (Nespoli, Besseghini, Pittaccio, Villa, & Viscuso, 2010).

### 2.1 Linear SMA mini actuators

Jansen et al. developed a linear actuator used for drive module for angular positioning (Jansen, Breidert, & Welp, 2004). It contains a 1000mm long wire with a diameter of 0.2mm wound on two sets of seven pulleys capable of reaching a displacement of 30mm when loaded at 4N, and the high force mode allows it to develop a displacement of 2.2mm at 56N (Figure 2). A bias spring is attached such that when the load exceeds a critical value, the circuit is opened and the SMA wire stops contacting. The maximum value can be adjusted by means of a screw (Jansen, Breidert, & Welp, 2004).

Strittmatter and Gumpel proposed an SMA actuator for actuation of a hydraulic valve. Figure 3 shows a schematic diagram of the prototype. When an electric current is applied, the SMA wires contact and cause the movable flange to shift and the flange is connected to a shaft that transfers the movement outside the closing screw (Strittmatter & Gumpel, 2004). When the energy supply is interrupted, a spring pulls back the shaft and the flange to the closing screw. Testing was carried out at a hydraulic pressure of 200bar, oil temperature of 24°C with two NiTi wires of 204µm. With a maximum current of 2.4A, the actuators show a stroke of 0.8mm against a force of 98N (provided by the spring) (Strittmatter & Gumpel, 2004).



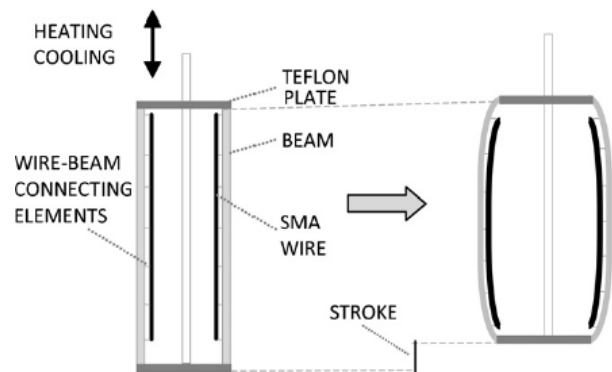
**Fig. 2. The drive module by Jansen et al. Figure 1: SMA Actuator by Strittmatter and Gumpel**

Haga et al. proposed a mini-actuator used in a Braille Display. It is made by using two counter-acting SMA springs having a 1.6mm diameter able to generate 10gf

(Haga, et al., 2005), (United States of America Patent No. US20080227060 A1, 2008).

Velazquez et al. developed an actuator used in case of a tactile binary information display made of two bias springs (Velazquez, Pissaloux, & Szewczyk, 2005). In this actuator, forced air circulation is used to decrease cooling time and we can get a stroke of about 3mm with 1.3A of current (Nespoli, Besseghini, Pittaccio, Villa, & Viscuso, 2010).

Elwaleed et al. developed an SMA beam actuator capable of amplifying SMA strain using elastic beams (Elwaleed, Mohamed, Mohd Nor, & Ma Tahir, 2005), (Elwaleed A. K., Mohamed, Mohd Nor, & Mohd, 2007), (Elwaleed A. K., Mohamed, Mohd Nor, & Mohd, 2008). In this experiment, a 150mm long 0.7mm diameter wire is eccentrically constrained on a flexible beam into six segments leading to the amplification of the deformation of wire deformation, with deformations up to 20mm (280% larger than those offered by the unconstrained wire) (Nespoli, Besseghini, Pittaccio, Villa, & Viscuso, 2010). When the temperature rises beyond the  $A^F$  temperature, the beam contracts and acts as a bias element for deforming back the wire. The actuator consists of two such beams connected to two plates (one fixed and the other able to move) and a shaft connected to the moving plate that transfers the movement outside the device. The actuator's dimensions are: 150 x 45 x 35 mm³ (Nespoli, Besseghini, Pittaccio, Villa, & Viscuso, 2010).



**Fig. 3. Schematic of the actuator by Elwaleed et al. (Elwaleed A. K., Mohamed, Mohd Nor, & Ma Tahir, 2005) (Elwaleed A. K., Mohamed, Mohd Nor, & Mohd, 2007) (Elwaleed A. K., Mohamed, Mohd Nor, & Mohd, 2008).**

### 3. SHAPE MEMORY ALLOYS – BIOMEDICAL APPLICATIONS

Although NiTi alloys are significantly more expensive than stainless steels, they have exhibited excellent properties for biomedical applications, such as, corrosion resistance (Hodgson, Ming, & Biermann, 1990), (Tadaki, Otsuka, & Shimizu, 1988), bio-compatibility (Mantovani, 2005),

(Ryhanen, et al., 1998) and non-magnetic (Mihalcz, 2001) which replicate those of the human body (tissues and bones) (Morgan, 2004) and can be manufactured to respond and change at the temperature of the human body (Machado & Savi, 2003).

The superelastic behavior of SMA, which fits the stress-strain behavior of human bone makes it an excellent choice for overcoming some of the challenges faced by stenting operations. SMA Stents are much more compliant of the bends in the blood vessels and the lumen while the stainless steel stents tend to force the blood vessel straight. Moreover, the SMA Stent can sustain the physiological loading encountered during normal use and provide a small outward force on the vessel during recovery making it ideal for stenting operations (Morgan, 2004).

Nowadays, due to the increase in demand for MIS treatment, the catheter-based surgeries have become more common. A laser machined SMA actuator proposed by Tung et al. allows for force, elongation, and size characteristics which are not achievable by the currently used coil and spring-based actuators (Tung, Park, Liang, & Niemeyer, 2008).

These are only the tip of the iceberg, SMAs are used for a variety of other biomedical applications as well, such as:

- Endodontics (Oh, et al., 2010)
- Medical tweezers (Jani, Leary, Subic, & Gibson, 2014)
- Sutures (Jani, Leary, Subic, & Gibson, 2014)
- Anchors for attaching tendon to bone (Jani, Leary, Subic, & Gibson, 2014)
- Implants(Pfeifer, et al., 2013)
- Aneurism treatments(United States of America Patent No. 5941249, 1999)
- Guide Wires(Lim, Park, Sugihara, Minami, & Esashi, 1996)

#### 4. FUTURE PROSPECTS

The future developments in SMAs can be expected at three different levels:

- Development of improved SMAs.
- Combination of the functional properties of SMAs with the structural properties of other materials to make hybrid or composite shape memory materials.
- Other new potential industries for SMAs are the Oil and Gas industries(Khan, Pequegnat, & Zhou, 2103), industrial and manufacturing sectors(Wu & Schteky, 2000), sports (Jani, Leary, Subic, & Gibson, 2014) and even arts (Descamps, 1991).

- Development and integration with CAD and FEA software will aid in the product development process.
- Development of SMMs with biodegradable capabilities to make implants that innocuously dissolve and are passed out of the body without the need for an operation to remove them.

#### 5. CONCLUSION

It is observed that SMA actuators are critical in the robotics field while also playing a role in catheters and implants in the biomedical fields, making them very favorable for miniature actuators as well as sensors. It is possible with the new design, analysis and manufacturing processes to take the flexibility and potential of SMAs to even greater heights.

In order to do so, some of the factors to consider during design are:

- Operating temperature range of the actuator
- The maximum deforming force and the maximum displacement to be produced.
- Durability, reliability, toxicity, corrosion resistance, electrical conductivity, hardness and strength all need to be considered when using SMAs as biomedical implants.
- The stroke length and the speed of the stroke are of prime importance, along with the cooling gradient being established in the case of actuating devices.
- We also require to optimize and fine tune the sensors and the controllers to ensure long life of the actuator.

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# Study of Latest Trends in Hybrid Electric Discharge Machining Process- A Review

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**Abstract:** Now a days, market has been flooded with advanced materials like super alloys, composites, ceramics, etc. These advanced materials can be easily machined by the use of non-conventional machining methods. Certain limitations regarding surface integrity, material removal rate, tool wear rate, geometric precision, etc are associated with these advanced processes. In order to offset these limitations and enhance machining capabilities, hybrid machining processes are developed. This paper presents the state of art Electric Discharge Machining (EDM) based hybrid machining processes such as Ultrasonic assisted EDM process, Laser assisted EDM process, Magnetic force assisted EDM process, Cryogenically Assisted EDM process, Electrochemical Discharge Machining process, Electric discharge abrasive grinding process, etc. Quality of the machined component is enhanced from the hybrid process instead of single process.

**Keywords:** EDM, USEDM, LAEDM, MFEDM, CEDM, ECDM, EDAG

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## 1. INTRODUCTION

In the present era of fast growing and changing technology, manufacturing industries have come under huge pressure to limit the use of conventional machining processes and adopt non-traditional machining processes which are capable to cut variety of extremely hard materials, able to generate complex contour profiles, high geometrical accuracy and excellent surface finish. The non-conventional machining processes use mechanical energy, thermal energy, chemical energy, and electrochemical energy as their modes for material removal. Mechanical energy based advanced machining processes are ultrasonic machining (USM), abrasive jet machining (AJM), water jet machining (WJM) and thermal energy based advanced machining processes are plasma arc machining (PAM), electrical discharge machining (EDM), and laser beam machining (LBM). Electrochemical machining (ECM) process uses electrical and chemical energy for material removal. Material is removed by erosion in mechanical based advanced machining processes. Ion Displacement results in loss of material in ECM process whereas melting and vaporisation are known to remove material in thermal based processes (Pandey and Shan, 2004).

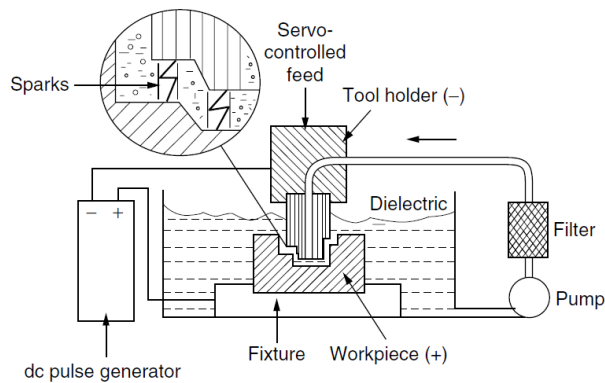
These non-traditional machining processes are marred by various limitations such as low material removal rate (MRR), poor surface finish, high specific energy consumption, high tool wear rate (TWR), and geometrical inaccuracies. In order to overcome these limitations, there is a dire need to develop hybrid machining processes. Hybrid machining processes (HMPs) combine two or more machining processes either co-instantaneously or successively, accommodating the advantages of included

processes. HMPs are categorized into primary HMPs (PHMPs) and secondary HMPs (SHMPs). In PHMP's, the constituent processes contribute to machining simultaneously whereas in SHMPs, one constituent process is completely dominating in nature and other process act as assisting processes in facilitating material removal. PHMPs are further classified into abrasion assisted HMPs (Abrasive wire cut electric discharge grinding and electric discharge abrasive grinding) and electrochemical based HMP's (Electrochemical discharge machining process). Similarly, SHMPs are classified into laser assisted HMPs (Laser assisted EDM, Laser assisted turning, laser assisted grinding), ultrasonic assisted HMPs (Ultrasonic assisted EDM, Ultrasonic assisted ECM, Ultrasonic assisted Drilling) and Magnetic force assisted HMPs (Magnetic force assisted EDM and Magnetic Force assisted ECM) (Lauwers, 2011).

## 2. ELECTRIC DISCHARGE MACHINING

EDM is used to machine conductive materials only. During the operation both tool and workpiece should be immersed in a dielectric medium (EDM oil, kerosene oil, etc.). The tool electrode is an exact replica of the shape of the cavity to be formed on the workpiece. Material is removed by a series of electric sparks between workpiece and tool. Hence, there is no direct contact between tool and workpiece. When a voltage of certain magnitude is applied between electrodes, electrostatic force comes into play. Free electrons from cathode surface start moving towards anode through spark gap. During this movement, free electrons collide with the molecules of dielectric medium and process of ionization takes place leading to the formation of more positive and negative ions. This process

continues and concentration of these ions becomes very high after fraction of seconds leading to the formation of plasma. During collision of free electrons with anode, kinetic energy gets converted into heat energy and temperature in the range 8000°C-12000°C develops. This high temperature is responsible for melting and vaporization of material. Similarly, collision of positive ions occurs at cathode, causing melting and vaporisation there (Boothroyd and Winston, 1989 and Mc. Geough, 1988). When the pulsating current is turned off, there occurs breakdown of plasma channel, causing the dielectric fluid to implore for plasma and remove molten metal by means of flushing. EDM set up is shown in Fig.1.



**Fig. 1. EDM set up (Hassan and El-Hofy, 2005)**

Various process parameters such as pulse on time, pulse off time, spark gap, duty cycle, polarity, tool rotation, flushing methods, geometry of tool, tool and workpiece material, etc can be studied to evaluate MRR, TWR, surface roughness (SR), heat affected zone, and recast layer, etc. Researchers have worked on various EDM variants namely wire EDM, micro EDM, dry EDM, rotating disc electrode EDM, powder mixed EDM, etc (Hassan and El-Hofy, 2005). EDM is widely used in automotive, defence, and aerospace sector. EDM also finds its application in nozzle, punches, and die manufacturing.

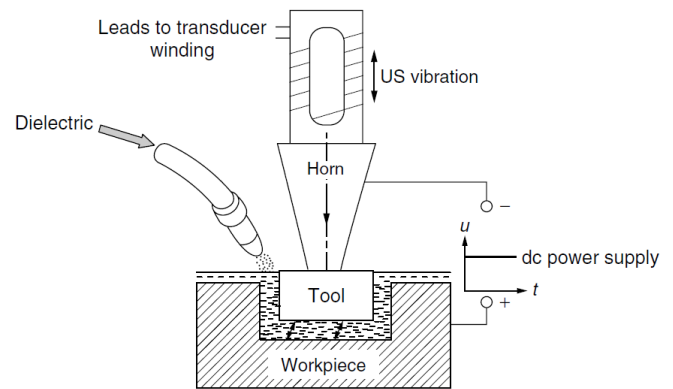
### 3. HYBRID ELECTRIC DISCHARGE MACHINING PROCESSES

In order to extend the scope of EDM process to machine non-conductive materials, improve MRR, ability to produce sharp edges, better handling of dielectric fluid, EDM has been combined with various other non-conventional processes. These hybrid processes are explained as follows-

#### 3.1 Ultrasonic Assisted EDM (USEDM)

USM gives low MRR but surface finish is quite good whereas in EDM, MRR is comparatively good but surface finish is poor. Both these processes can be combined to form Ultrasonic assisted EDM process. In USEDMD, material is removed by the combined action of ultrasonic vibration of workpiece (or tool) and electric discharges

produced between electrodes. Tool is generally given motion perpendicular to the workpiece surface. The abrasive slurry used in USM process is completely replaced by dielectric fluid. Tool or workpiece vibration enhances the fresh circulation of dielectric fluid to the machining zone and facilitates in removing debris away from machining zone (Kozak and Rajurkar, 2001). USEDMD can be used to fabricate non circular shaped micro products. Micro holes of high aspect ratio can also be created using this process. The schematic diagram of set up of USEDMD is shown in Fig.2.



**Fig. 2. USEDMD set up (Hassan and El-Hofy, 2005)**

Wansheng et al. (2002) succeeded in machining small and deep holes of diameter 0.2 mm with aspect ratio greater than 15 in titanium alloy Ti-6Al-4V using USEDMD. Earlier, it was difficult to create holes in titanium based alloys using EDM due to very high tensile strength and low heating conductivity of titanium. Thus, USEDMD paved a way for machining titanium based alloys. Goigana et al. (2016) used pulsed USEDMD process for improving surface roughness during finishing operation of 1.234 alloy steel (tempered) using copper tool. Improvement in homogeneity and surface roughness was observed in machined surfaces. Zhixin et al. (1995) developed a set up of ultrasonic pulse assisted electric discharge machining process for creating holes in ceramic material. Researchers achieved high MRR during their experimentation.

#### 3.2 Laser Assisted EDM (LAEDM)

Laser is characterised by its good machining capabilities and poor surface quality. Contrary to it, EDM is known to have good accuracy and poor machining rate. Thus process capabilities of both laser and EDM can be used to develop hybrid process called as Laser Assisted EDM. Li et al. (2006) used LAEDMD process for micro drilling of fuel injection nozzles using laser drilling for production of micro holes followed by rimming of micro holes. The researchers observed elimination of heat affected zone and recast layer. There was 70% reduction in time during drilling process with the help of laser assisted EDM. Al-

Ahmari et al. (2016) performed machining of shape memory alloy based on nickel and titanium using laser assisted micro EDM process. The holes were first drilled using laser and rimming was carried out using micro EDM. The hybrid process reduced machining time by 50-65%. Liang et al. (2002) used Nd-YAG laser based micro EDM process for pin and plate assembly on a micro scale. Wire Electric Discharge Grinding was used for machining of pin for fusing into plate. Thus, assembly was done using laser and machining was performed using one of the EDM variants. As a result of this, the positioning accuracy and perpendicularity of pin and plate can be easily maintained and smooth joint between pin and plate is developed.

### 3.3 Electrochemical Discharge Machining (ECDM)

EDM is used for machining of conductive materials only, combining it with ECM can overcome this limitation. When ECM is combined with EDM, then this process is called as

Electrochemical Discharge Machining process. In this process, form of tool is exactly mirrored on the attached workpiece. The complete set up of ECDM process has been shown in Fig.3.

Sarkar et al. (2006) successfully performed electrochemical discharge machining on silicon nitride based ceramics. They also developed second order mathematical model (non-linear) for obtaining relationship among various machining parameters. Applied voltage prominently affected MRR and heat affected zone as reported by researchers. Coteata et al. (2008) were able to generate holes successfully with a diameter less than 1mm in cutting steel using ECDM with sodium silicate as working fluid in the hybrid process. Saini et al. (2016) successfully used ECDM for micromachining of composite made of E- glass fibre and epoxy. It was observed that electrolytic concentration has significant effect on material removal rate of polymeric composite.

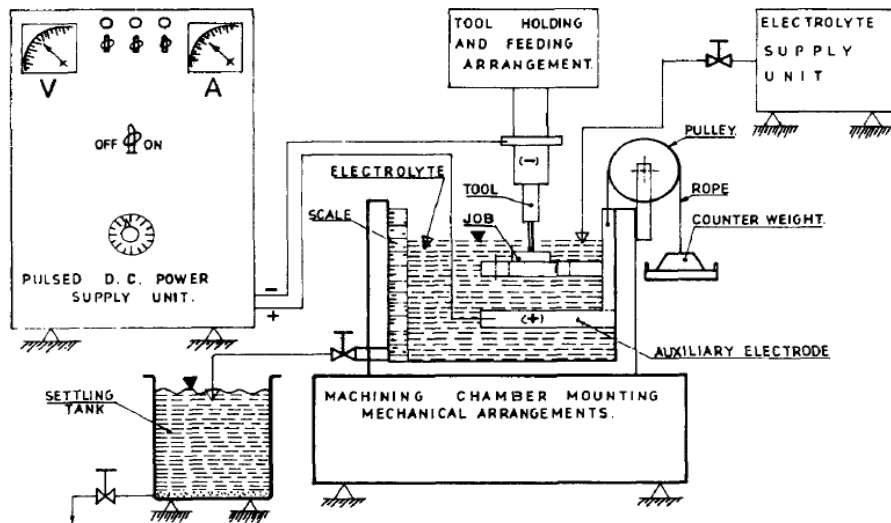


Fig. 3. ECDM set up (Sarkar, Doloi and Bhattacharyya, 2006)

### 3.4 EDM and Chemical Machining

Wang et al. (2011) fabricated silicon wafers by slicing of silicon ingots using Wire EDM and anodic etching.

### 3.5 Abrasive Jet Aided EDM

Arantes et al. (2016) combined Electric Discharge Machining process with pressurized jet of dielectric containing SiC abrasives (600 mesh) for machining of high speed steel of grade AISI M2 using copper electrode. Kerosene oil, deionised water, and mineral oil were used as dielectric fluids with pressure varying from 0 to 100 bar. MRR increased eight times in hybrid process as compared to EDM. MRR and surface roughness values were highly affected by flushing pressure, as higher pressure of dielectric fluid enhances material removal from the machining zone. The authors also reported significant

increase of SR using SiC particles. Lin et al. (2012) evaluated the machining performance of SKD 61 steel in abrasive EDM using copper tool and abrasives of SiC and  $Al_2O_3$ . The striking pressure of abrasive particles was varied from 0.3 to 0.9 MPa, keeping constant flow at 6 g/min. The researchers observed significant improvement in machining efficiency and surface quality with this hybrid process. Hence, this hybrid process can successfully fill the major requirements of manufacturing industry.

### 3.6 Electric Discharge Abrasive Grinding (EDAG)

Koshy et al. (1996) explained the mechanism of material removal in hybrid electric discharge diamond grinding process. The authors reported the successful machining of various carbide-steel combinations and other materials which continuously load the wheel. Dressing and

declogging of the grinding wheel is a necessary aspect while machining. The authors also observed that workpiece material is softened by spark discharges, thereby, reducing normal force and grinding. Owing to this thermal softening effect, the expensive diamond abrasive particles can be replaced by  $\text{Al}_2\text{O}_3$  particles in EDAG process as shown in Fig.4.

Unune et al. (2016) experimentally investigated electric discharge diamond grinding of Nimonic 80A alloy. It was reported that MRR is highly influenced by wheel speed, powder concentration and current. Baghel et al. (2016) performed machining of  $\text{TiN-Al}_2\text{O}_3$  ceramics using diamond grinding assisted EDM. The researchers observed simultaneous working of diamond grinding and EDM in this process. MRR was found to be more in this process as compared to EDM alone. Working on the same lines, Choudhary et al. (1999) performed electric discharge diamond grinding of high speed steel. MRR increased with increase in pulse on time and current. Decrease in MRR was found with increasing duty factor and voltage.

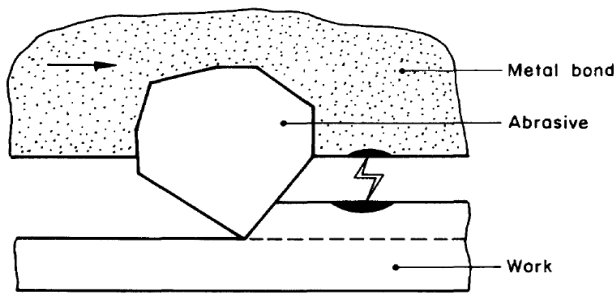


Fig. 4. Schematic representation of EDAG (Koshy, Jain and Lal, 1996)

### 3.7 Cryogenically Assisted EDM (CEDM)

Goyal et al. (2017) extended their work in evaluating the performance of cryogenically assisted EDM process. The researchers machined cryogenically treated and untreated steel (AISI D2) by cryogenically cooled, treated and untreated copper electrodes. 18% increase in MRR, decrease of 26% in TWR and decrease of 11% in surface roughness were reported. Best results were yielded by the combination of cryogenically untreated workpiece and cryogenically treated tool. Abdulkareem et al. (2010) machined titanium alloy Ti-6Al-4V with customized CEDM using copper electrode which was cooled constantly. Significant reduction in electrode wear by 27% and SR by 8% was obtained by this process. Jafferson and Hariharan (2013) used three different tools namely tungsten, copper, and brass for machining of AISI 304 stainless steel using CEDM. The performance of cryogenically treated and untreated tools were evaluated. 58% reduction in TWR in cryogenically treated tungsten electrode was observed. Successful attempt is reported to

extend the scope of CEDM to ultrasonic assisted CEDM (UACEDM) (Srivastava and Pandey, 2012).

### 3.8 Magnetic Force Assisted EDM (MFEDM)

Lin et al. (2009) merged EDM with magnetic forces for machining SKD 61 steel as shown in Fig.5. In this hybrid process, the debris is expelled quickly due to assisting magnetic field. MRR was increased three times as compared to standard EDM along with reduction of micro cracks in machined steel. Singh et al. (2016) used MFEDM for machining Al based metal matrix composites. Reduction in recast layer and 12.9% improvement in MRR were reported.

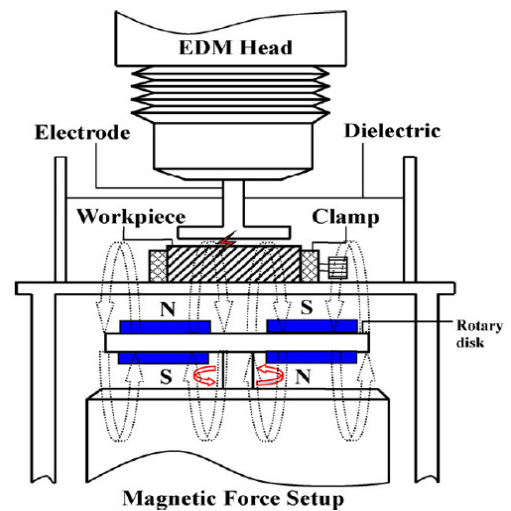


Fig. 5. MFEDM set up (Lin et al., 2009)

## 4. CONCLUSION

On the basis of discussion, it can be concluded that EDM can be successfully hybridized with other non-traditional machining processes. Significant improvement in MRR in most of the hybrid processes has been observed in comparison to EDM only. Electrical and non-electrical parameters play an important role in affecting MRR, TWR and surface roughness. Contribution of EDM based hybrid processes for machining hard and advanced materials have proved it to be the most precise and advanced machining process.

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# Parameter Optimization of Electro Discharge Machine: A Review

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**Abstract:** Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes, based on thermoelectric energy between the workpiece and an electrode. In this process, the material is removed electro thermally by a series of successive discrete discharges between two electrically conductive objects, i.e., the electrode and the workpiece. The performance of the process, to a large extent, depends on the material, design and manufacturing method of the electrodes. The optimization of the parameters of the EDM machining has been carried out by using the various method for design of experiments (DOE) and optimization for the process parameter is done.

**Keywords:** EDM, Process parameters, tool wear rate, MRR.

## 1. INTRODUCTION

Electrical discharge machining is non-conventional material removal process. This process is used to produce dies, punches and moulds, finishing parts for aerospace and automotive industry and surgical components [Bhola et al., 2011]. The EDM is used to machine electrically conductive workpieces irrespective of their hardness, shape and toughness. During process of EDM, the electrode shape is mirrored in the workpiece. The electrode dimensions are in such a way that spark gap between the surface to be generated and electrode is maintained as shown in Figure 1. More gap is required for higher removal rate but higher gap may results in poor surface quality. The performance of the EDM process is dependent on the material and the design of the electrodes.

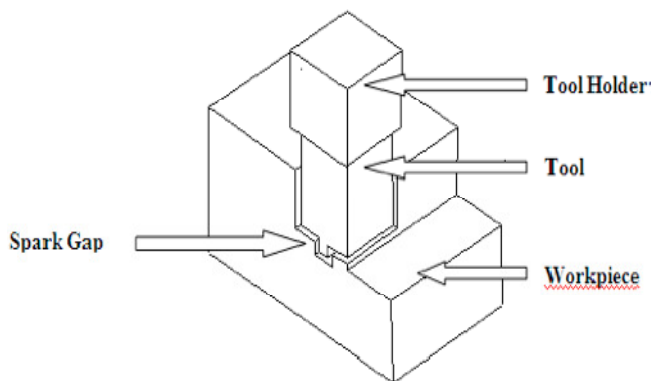


Fig. 1. Electrode and the workpiece[Bhola et al., 2011].

The electrode has two parts, electrode tool and holder. Both of these parts are usually designed and manufactured into single piece. The simple electrodes are usually manufactured by conventional cutting methods, but machining, casting, electroforming or metal spraying may

produce complicated shape electrodes. The output responses MRR, TWR and SR are conflicting in nature. MRR reflects the productivity and tool wear reflects the accuracy of the product. So in this work it was proposed to study the effects of different input parameter current, pulse on time and pulse off time on Material removal rate, Tool wear rate and Surface roughness with EDM oil as a dielectric[Chandramouli et al., 2014].

In die-sinkingtype electrical discharge machining process, in general, either fixed electrodes are used to produce die cavities or a rotary device works in conjunction with a CNC to control the electrode's path in various EDM profiling. Manufacturing method of electrode can affects manufacturing time, cost and performance of EDM electrode.

In present scenario, EDM is used as one of the standard technique for manufacturing production tooling out of hardened materials for production of dies and moulds. Due to rapid tool wear involved; many electrodes perform the operation to machining each cavity. Tool wear affects machining accuracy, surface roughness of the workpiece and demand for frequent tool replacement adding to around 50% of tooling cost. Alternatively use of rapid tooling technique can minimizes the electrode development lead-time and reduces the tooling cost considerably. This is the reason that, design, development and manufacturing of EDM electrode play a very vital role in EDM technology. A lot of published EDM research work relates to parameter optimization for a particular work tool interface or to determine best tool material for a particular work material. Many innovative electrode material and designs have also been tried. The objective of this review paper is to report and review the research work carried out by researchers in the field of EDM electrode design and manufacturing



## 2. MONITORING AND CONTROL OF THE EDM PROCESS

The EDM process parameters to be monitored during the machining process so that the controlling of these parameters can be done to obtain the required response parameters. The main purpose of monitoring and controlling the process is to observe and measure process parameters to reduce the deviation which incurred in the experiment and to reduce the deviation of performance measures from the expected level. An adaptive control system for process monitoring, identification and control in the wire electrical discharge machining process has been developed by Yan et al., 2010. It has been observed that the wire breaking has to be controlled by adjustment of pulse interval of each pulse cycle of supply. Caydas et al., 2008 developed an adaptive neuro-fuzzy inference system model for the prediction of the surface roughness of machined surface using wire EDM process as a function of process parameters such as open circuit voltage, pulse duration and wire feed rate [Caydas 2008]. From the experimental results, it has been found by the results that the control system has improved the surface quality in EDM process. Yilmaz et al. introduced a user friendly intelligent system based on the knowledge of the skilled operators for the selection of the EDM process parameters for machining AISI 4340 stainless steel [Yilmaz, 2006].

## 3. LITERATURE REVIEW

In this paper few selected research paper related to Die-sinker EDM with effect of MRR, TWR, surface roughness (SR) and work piece material have been discussed.

Vishnu D Asal et al. conducted experiment [Asal et al., 2013] on Process parameters of EDM by using the ANOVA method. In this experiment, he has taken two level of current, tool material, and spark gap are kept as the main variable. The material used was S.S.304 as the work piece and copper and brass material as the tool electrode and dielectric fluid used is DEF-92. The design of experiment is used to design the EDM experiments. The various tool of DOE are used to analyze the final result of the experiment performed with the help of graphs in research. The analysis is being done in mini-tab 15 software. ANOVA is performed to identify the statistical significance of parameters

Chandramouli S et al. 2014 conducted investigating EDM process parameters by using the Taguchi method and select the optimum result from the experiment performed. The effect of various process parameter on machining performance is investigated by the method which is based on Taguchi method. They use the input parameters as current, pulse time on, and pulse time off and the other side of Material removal rate (MRR), Tool wear rate (TWR), and surface roughness (SR). The taguchi method is used for formulating the experimental layout, ANOVA method is

used to analysis the effect of input parameters on machining characteristics and find the optimum process parameters

Nilesh, 2013 optimizing of various parameters which are affected on different types of machining characteristics of EDM. The objective of this paper is to investigate the optimum cutting parameters for a work piece of SS 304 & tool material use as copper, aluminum and brass combination on fuzzy logic control based EDM. This experiment was accomplished by Taguchi Method. In this paper they use process parameters are Current, spark gap voltage, Ton, and Toff. And at the other side of output they use MRR, TWR, and SR. In the paper they conclude that the Gap voltage has highest effect on MRR

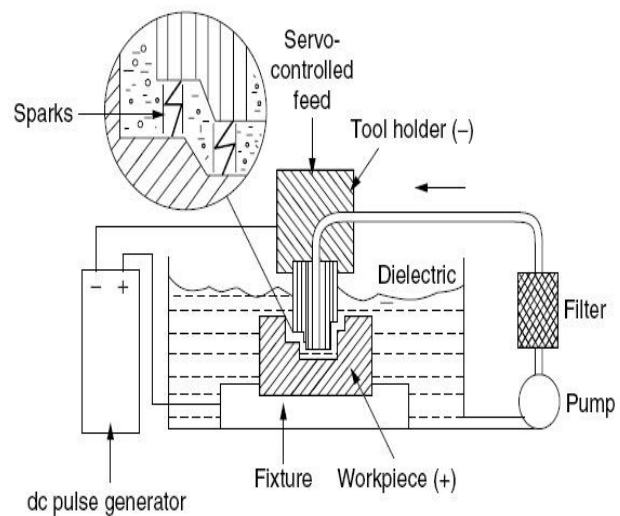


Fig. 2. Working principle of EDM [8]

Vishal J Nadpara et al., 2014 performed used AISI D3 tool steel to perform the experiment and used graphite electrode of 10 mm diameter. The process parameters are considered on the basis of Taguchi Method. The objective of the paper is to optimize the process parameters of machining in high, Medium and low wear factors through duty cycle. In this paper to perform experiment the input process parameters considered are current, duty cycle and pulse time ON and the opposite side the output process parameters as MRR and EWR. In this they also used as taguchi method for getting the optimum result of selecting the best process parameters

## 4. CONCLUSIONS

The conclusions of this discussion are as follows:

1. It has been found that Ton has mostly significant effect on the material removal rate (MRR) while the Toff has least effect on material removal rate (MRR).
2. If the current is higher than the Material Removal Rate is greater with respect to the Toff time



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# Experimental Analysis of Automatic Stirrup Bending Machine

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**Abstract:** The stirrup is the key component of a structure, for increment quality and life of the building. Stirrup requires fit as a fiddle of the square, rectangle or trapezoidal shape which relies upon kind of structure. In greater part case today likewise, stirrup twist utilizing labor work only. Albeit numerous hardware accessible for programmed stirrup bending, individuals lean toward manual twisting operation in light of some limitation of Auto-machine. Automatic stirrup bending machines are heavy and immovable, a skilled person requires, impossible to locate every construction site, adaptable for large construction site otherwise it becomes uneconomical, etc. for this problem we introduce one mechanism which movable, automatic & economical. This paper includes the Experimental design of Automatic Stirrup Bending with considering factorial design. Bending angle is an important factor for stirrup and experiment of stirrup bending angle was designed using full factorial design with two level for each factor (2k factorial design). Since here considered three factor, each at two level, the design is 2³ factorial design. Factor taken for experiment work are the diameter of the stirrup rod, length of stirrup required to bend and the inclination angle of the hydraulic piston from the reference line.

**Keywords:** Stirrup, Bending, Arduino Controller, Cylinder.

## 1. INTRODUCTION

During the construction of any building columns, beams and slabs are used for supporting the whole structure. Also, these sections or bars are should have been tied with rectangular or square bars called stirrup, which is kept at specific separations, contingent upon the plan of structure. But the major problem faced in using these stirrups is they are required in large numbers because of the support purpose. And as the number of beams or the columns increases the number of stirrup required increases. So the labor cost matters a lot in bending of these stirrups and in addition to the cost of a lot of time is invested in bending of these stirrups. Manual operation for bending of stirrup shown in the following figure.



Fig. 1. Manual stirrup bending operation

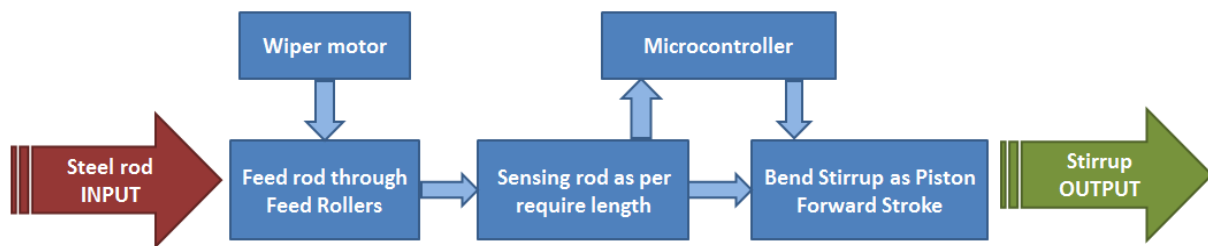
So, here designed an Automated Stirrup Bending (ASB) that will produce readymade stirrups which can be directly utilized in the structures. And hence bringing a drastic reduction in time required for bending stirrups, labor cost and the construction lead time. In this paper, 3 variables considered for bending of stirrup using automatic stirrup bending (ASB) with a level of 2 for each variable. By incorporating analysis of variance for factorial design, best level of variables is determined.

## 2. AUTOMATIC STIRRUP BENDING METHOD

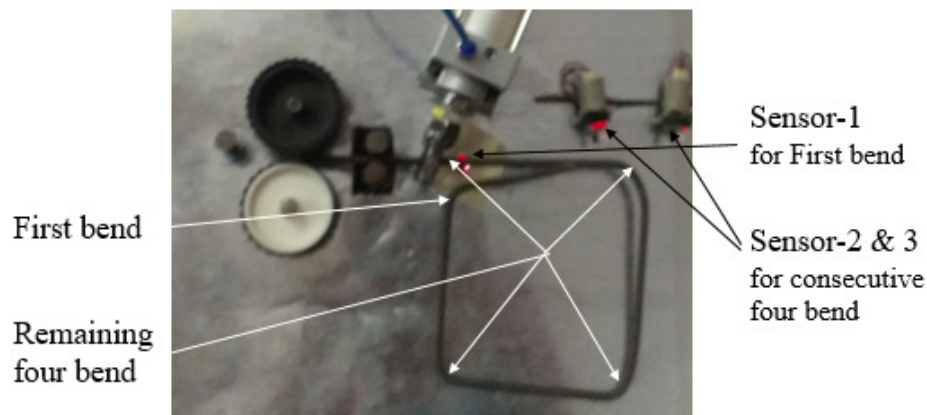
Automatic stirrup bending includes a pneumatic system, controller, sensor, and roller mechanism. Hydraulic piston cylinder use to provide bending force to stirrup under control of the controller. Sensors used to sense the availability of rod at the specific position depending on required length to be bend. Roller mechanism gives intermittent motion to stirrup rod for continuous bending up to last consecutive bend. Stirrup requires for different structure include various shapes i.e. square, rectangle, trapezoidal, depending on structure design.

### 2.1 Basic Design and Construction

For automatic stirrup bending, the stirrup rod is input from feed roller under control of first sensor and controller. Feeding action of roller applied with wiper motor. Here the first sensor used to provide initial bend, which followed by other two sensors, used to provide remaining four bending as required size and shape of the stirrup. After sensing rod by a sensor, piston forward stroke provide for bending stirrup.



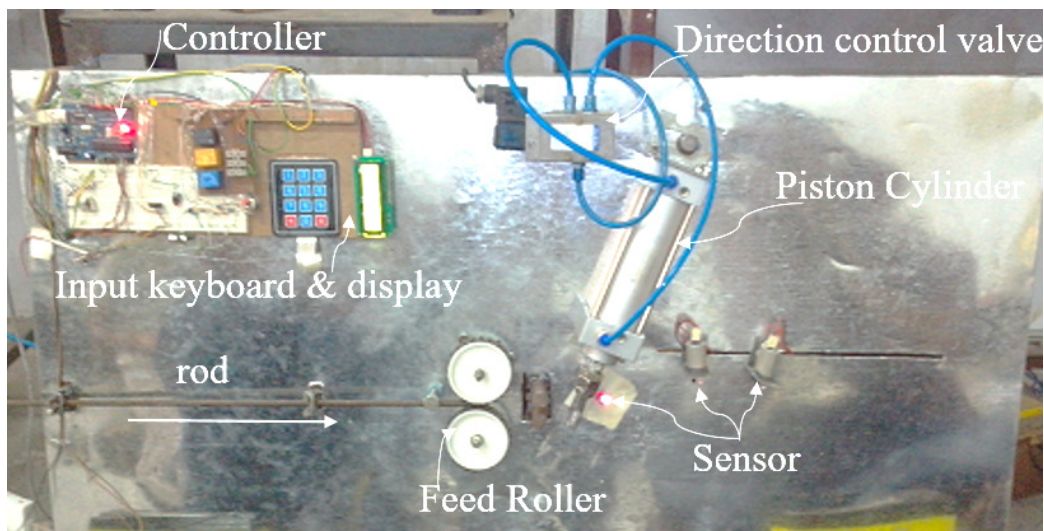
**Fig. 2. Basic block diagram for stirrup bending machine**



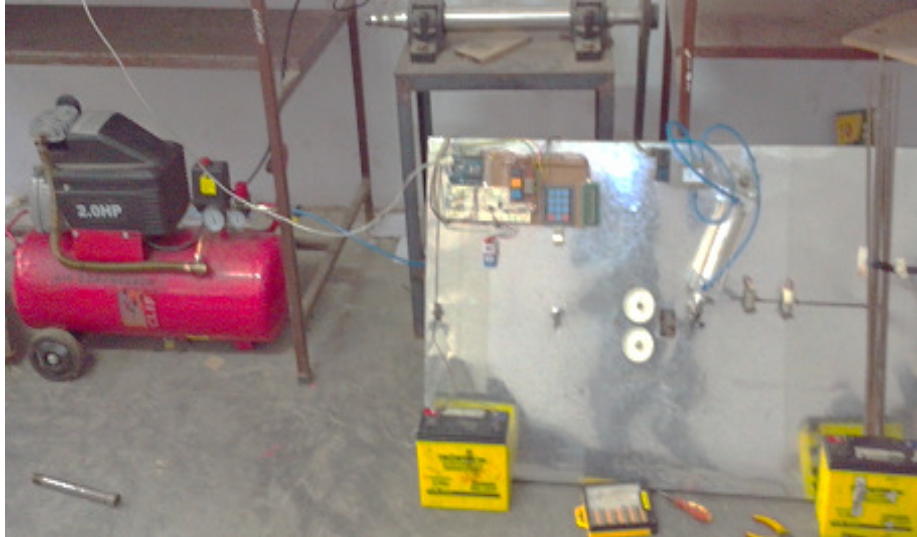
**Fig. 3. Output stirrup with after four consecutive bend**

In bending machine used The ArduinoDiecimila, microcontroller board based on the ATmega 328 with 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs and 16 MHz crystal oscillator. In the model, Wiper motor used for controlling feed motion as it is economical offers and higher torque with capacity 12V DC supply and speed achieved is nearly 70 RPM. It is

required to detect the presence of rod in the 2-3cm vicinity and give the signal to the controller, here Optical sensor used. A 5/2 directional control valve with piston cylinder provides bending force to a rod. Single acting spring return cylinder is used to bend the rod. Forward stroke is due to air pressure and return stroke is by automatic spring return.



**Fig. 4. Automatic Stirrup Bending Setup**



**Fig. 5. Operational Setup of Mechanism**

### 3. EXPERIMENT DATA

#### 3.1 Objective of experiment

- Incorporate fundamental relationship between parameters of stirrup bending.
- Gather data on most effective parameter for given stirrup constraints.
- Use result of analysis for understanding stirrup bending parameters and their relationship.

#### 3.2 Experimental Work

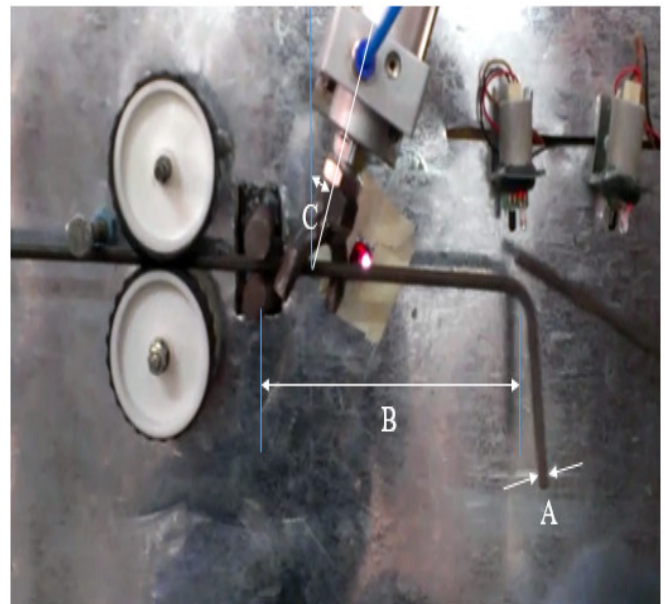
For perfect bending of the stirrup, it requires incorporating spring back effect of the stirrup rod, which is the main interrupt in this mechanism. To eliminate spring back effect, inclination provides to a cylinder with the vertical reference line ( $25^\circ$  to  $30^\circ$ ). Also bending rod length varies with the size of stirrup which directly depends on construction application.

The process of stirrup bending is including as an art because of a large amount of variability and subjectivity involved. Inconsistency in the result of bending angle increase because of variability in parameters of operation. As describe cylinder angle, length of the rod to be bend and diameter of the rod is only variable for perfect bending of the stirrup.

**TABLE 1: Considerable parameters for Stirrup Bending**

Controllable Parameters	Cylinder angle with reference line, length of rod, diameter of rod
Response Parameters	Stirrup internal angle

The factorial design used to be most effective for an experiment that involves effect of the study of more number of parameters at a time. For measurement of the internal angle of the stirrup, bevel protector is used with two significant digit accuracy after the decimal place.



**Fig. 6. Considered parameters**

**TABLE 2: Factors and respective level**

Factors	Levels
Diameter of Rod	6 mm & 8 mm
Length of Rod	10 mm & 12 mm
Cylinder angle	$25^\circ$ & $30^\circ$

### 3.3 Experimental Results

**TABLE 3: Stirrup internal angle**

Diameter of Rod (A)	length (B)			
	10		12	
	angle (C)		angle (C)	
	25	30	25	30
6	95.23	92.34	95.34	87.92
	97.67	94.32	92.32	88.8
8	99.04	96.54	96.54	88.97
	98.87	95.43	96.54	88.43

**TABLE 4: 2³ effect table**

Treatment Combination	Coded Factors			Spread		Total
	A	B	C	Replicate 1	Replicate 2	
1	-	-	-	95.23	97.67	192.9
a	+	-	-	99.04	98.87	197.91
b	-	+	-	95.34	92.32	187.66
ab	+	+	-	96.54	96.54	193.08
c	-	-	+	92.34	94.32	186.66
ac	+	-	+	96.54	95.43	191.97
bc	-	+	+	87.92	88.8	176.72
abc	+	+	+	88.97	88.43	177.4

Sum of Squares:

$$SS_A = \frac{(\text{contrast } A)^2}{8n} = \frac{(\text{effect of } A \times 4n)^2}{8n} = 16.851025$$

$$SS_B = \frac{(\text{contrast } B)^2}{8n} = \frac{(\text{effect of } B \times 4n)^2}{8n} = 74.736025$$

$$SS_C = \frac{(\text{contrast } C)^2}{8n} = \frac{(\text{effect of } C \times 4n)^2}{8n} = 94.09$$

$$SS_{AB} = \frac{(\text{contrast } AB)^2}{8n} = \frac{(\text{effect of } AB \times 4n)^2}{8n} = 1.113025$$

$$SS_{BC} = \frac{(\text{contrast } BC)^2}{8n} = \frac{(\text{effect of } BC \times 4n)^2}{8n} = 1.2321$$

$$SS_{AC} = \frac{(\text{contrast } AC)^2}{8n} = \frac{(\text{effect of } AC \times 4n)^2}{8n} = 13.0321$$

$$SS_{ABC} = \frac{(\text{contrast } ABC)^2}{8n} = \frac{(\text{effect of } ABC \times 4n)^2}{8n} = 1.5876$$

$$SS_{\text{total}} = \sum_{i=1}^a \sum_{j=1}^b \sum_{k=1}^c y_{ijk}^2 - \frac{y^2}{8n}$$

$$= (141645.7) - \frac{1504.3^2}{8 \times 2}$$

$$= 213.302575$$

$$SS_{\text{error}} = SS_{\text{total}} - SS_A - SS_B - SS_C - SS_{AB} - SS_{BC} - SS_{AC} - SS_{ABC}$$

$$= 10.6607$$

$$SS_{\text{model}} = SS_A + SS_B + SS_C + SS_{AB} + SS_{BC} + SS_{AC} + SS_{ABC}$$

$$= 202.641875$$



TABLE 5: ANOVA for stirrup angle

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F ₀		F _{table} F _{0.05, 1, 8}	Significant/ unsignificant
A	16.851025	1	16.85103	12.64534	}	5.32	Significant
B	74.736025	1	74.73603	56.08339			Significant
C	94.09	1	94.09	70.607			Significant
AB	1.113025	1	1.113025	0.835236			Unsignificant
BC	1.2321	1	1.2321	0.924592			Unsignificant
AC	13.0321	1	13.0321	9.779545			Significant
ABC	1.5876	1	1.5876	1.191366			Unsignificant
Error	10.6607	8					
Total	213.302575	15					

Contribution of each parameter on model:

$$\text{Contribution of A (\%)} = \frac{16.851025}{202.641875} \times 100\% = 8.315385 \%$$

$$\text{Contribution of B (\%)} = \frac{74.736025}{202.641875} \times 100\% = 36.879588 \%$$

$$\text{Contribution of C (\%)} = \frac{94.09}{202.641875} \times 100\% = 46.430091 \%$$

$$\text{Combined Contribution of AB (\%)} = \frac{1.113025}{202.641875} \times 100\% = 0.549238 \%$$

$$\text{Combined Contribution of BC (\%)} = \frac{1.2321}{202.641875} \times 100\% = 0.607997 \%$$

$$\text{Combined Contribution of AC (\%)} = \frac{13.0321}{202.641875} \times 100\% = 6.430881 \%$$

$$\text{Combined Contribution of ABC (\%)} = \frac{1.5876}{202.641875} \times 100\% = 0.783424 \%$$

### 3.4 2³ factorial design model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{23} x_2 x_3 + \beta_{13} x_1 x_3 + \beta_{123} x_1 x_2 x_3$$

Where,  $y$  = function model (stirrup angle)

$x_1, x_2, x_3$  = diameter of rod, length of rod and cylinder angle

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_{12}, \beta_{23}, \beta_{13}, \beta_{123}$  = coefficients

$$\beta_0 = \frac{\sum_{i=1}^a \sum_{j=1}^b \sum_{k=1}^c \sum_{l=1}^d y_{ijkl}}{abcn} = \frac{1504.3}{16} = 94.01875$$

$$\beta_1 = \frac{\text{effect of A}}{2} = \frac{2.0525}{2} = 1.02625$$

$$\beta_2 = \frac{\text{effect of B}}{2} = \frac{-4.3225}{2} = -2.16125$$

$$\beta_3 = \frac{\text{effect of C}}{2} = \frac{-4.85}{2} = -2.425$$

$$\beta_{12} = \frac{\text{effect of AB}}{2} = \frac{-0.5275}{2} = -0.26375$$

$$\beta_{23} = \frac{\text{effect of BC}}{2} = \frac{-0.555}{2} = -0.2775$$

$$\beta_{13} = \frac{\text{effect of AC}}{2} = \frac{-1.805}{2} = -0.9025$$

$$\beta_{123} = \frac{\text{effect of ABC}}{2} = \frac{-0.63}{2} = -0.315$$

From above experimental analysis, it appears that length of the rod, the diameter of the rod, cylinder angle with reference line significantly effects on a stirrup internal angle. Additionally, combine effect of rod length and cylinder angle is significantly affected. Following graph represents the effect of all three parameters at both level, include combining effect of two variable i.e. length of rod and cylinder angle.

#### 4. RESULT

From above analysis of factorial design, three main parameters and one interaction effect are significant which is shown in following result graphically.

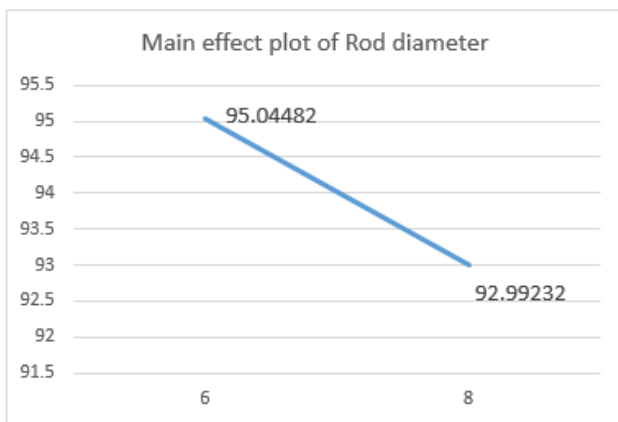


Fig. 7. Main effect plot of rod diameter

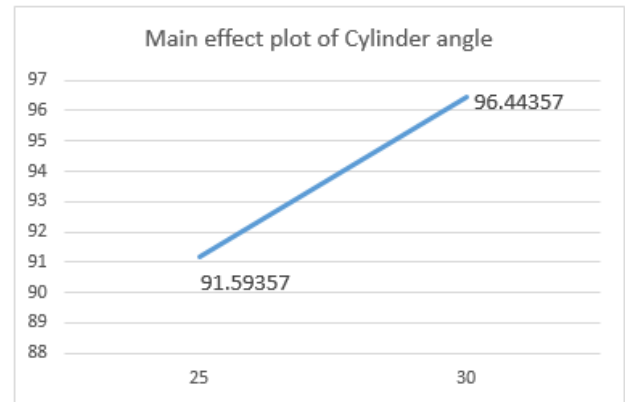


Fig. 8. Main effect plot of cylinder angle

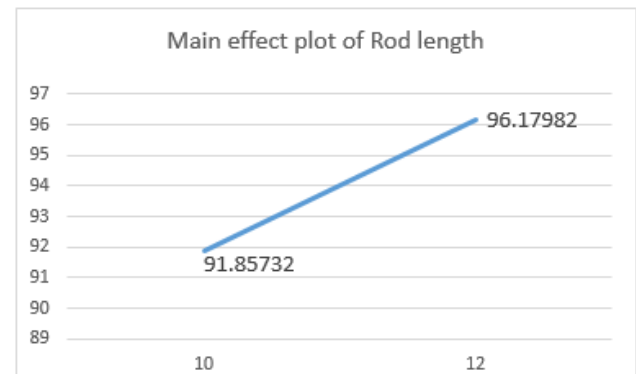


Fig. 9. Main effect plot of rod length

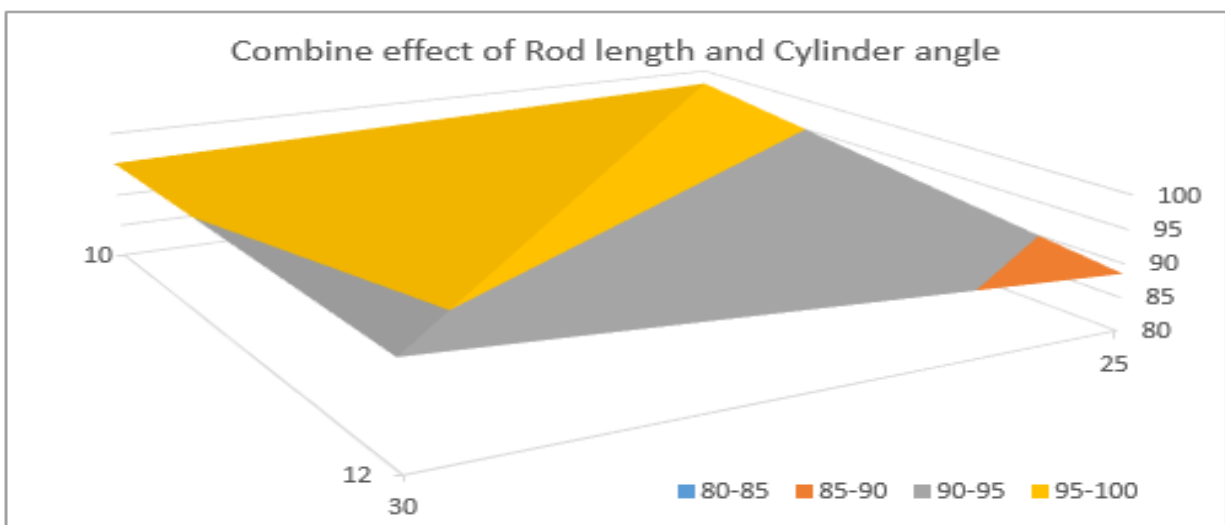


Fig. 10. Combine effect of rod length and cylinder angle

#### 5. CONCLUSION

From the Design of Experiment of stirrup angle, gives that main effects of parameters and interaction effect of one pair

are significant. Percentage contributions are the length of a rod having 36.8795%, the diameter of a rod having 8.3153%, the angle of a cylinder having 46.43% and combine effect contribution 6.43% on a stirrup angle. Here

from main effect plot of angle, v/s rod length (fig.9) rod length should be at lower level. On the same way, diameter (fig.7) should be at a lower level and cylinder angle (fig.8) should be at lower level. For combine effect length of rod and angle of the cylinder should be at higher and lower level respectively.

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# Tensile Behavior of Hybrid Polymer Nano-composite Reinforced by $\text{Al}_2\text{O}_3$ Rod and Spherical Shape Nano Particles

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**Abstract:** Particulate composite reinforced with Nanofillers are getting increased attention because of their improved tensile and elastic properties. In this work alumina ( $\text{Al}_2\text{O}_3$ ), with rod and sphere shape Nanofillers are used in the fabrication of hybrid epoxy composites. Probe sonicator has also been used for the proper mixing of Nanofillers in the vicinity of epoxy matrix, finally for making the hybrid composites. The dimensions of the Nanorods and spherical particles are 15-30nm diameter & 50nm in length and diameter 20-50nm respectively. Three different types of samples with weight fraction of 0.5%, 1% and 1.5% of Nanofillers are prepared by in-situ polymerization technique. The ASTM standard D638 is followed in the preparation of the samples. A series of unidirectional tensile tests has been performed on the fabricated samples. Best result has been obtained with 1.0 wt. % hybrid composites as compared to the composite without Nanofillers. This may be attributed to the good dispersion of Nanofillers in epoxy matrix. Tensile strength was found to be improved by 9% for 1.0 wt. % sample as compare to 0.5 and 1.5 wt. % hybrid composites. A decline in the properties was also noticed at higher wt. % i.e. 1.5 hybrid composites. This may be due to the agglomerations of the filler particles as they have been used in different l/d ratios. Further Morphology of fracture surfaces has also been detected through optical microscopy at 1000X scale. More roughness of fracture surface indicates more energy absorbed during fracture. This experimental work provides the better insight to the researchers working for the materials to be developed for special coatings.

**Keywords:** Hybrid Polymer Nanocomposite, tensile behavior, in-situ polymerization, Alumina Nanoparticles

## 1. INTRODUCTION

The development in the industrialized processes and material science has led to development of new composite materials, one such material is reinforcement based polymer composite. Polymeric composite materials are widely used in applications as the following: weight sensitive, high specific strength, stiffness, high wear resistance, excellent corrosion & chemical resistance, high dimensional stability. [Khashaba, 2006]. Highly brittle characteristics of epoxy in term of resistance against cracks initiation and propagation are drawback [Shukla and Parmeswaram, 2007]. Tensile strength enhancement with MWCNT reinforced in epoxy [Zhou et al., 2007]. Increment of 34% in fracture toughness was observed for alumina nano rods at 1.5 wt% over that of neat epoxy and alumina nano rods of higher aspect ratio on the same weight fraction fracture toughness was enhanced 56 % for nanocomposites [Shukla et al., 2013]. Tensile strength of hybrid is high compare to aramid composite and plane composite of 1% nanoparticle alumina [Charvani et al., 2015]. Failure strain and Tensile strength increased 31% & 20% at 0.5% & 1% wt% of alumina nano rod elastic modulus increase with increase in wt% of nano rod, max 14% at 1% wt% of nano rod [verma et al., 2014]. Moderate increase in the elastic modulus and tensile strength of epoxy-clay nanocomposites at very low volume fraction of

clay [Daniel, 2003]. However at higher volume fraction (10%) the elastic modulus increased by 90% whereas the tensile strength decreased by 44%. Fracture toughness increased 57% and showed not suitable improvement in tensile strength and modulus [8]. Improvement in Alumina and its alloys property, SiC with  $\text{Al}_2\text{O}_3$  reinforced and also mechanical property tensile strength, hardness, density and wear resistance increased [NarayanaMurty, 2003]. Present work is concentrated on hybrid reinforced effect of  $\text{Al}_2\text{O}_3$  nanoparticles of different size and shape taken are, i) spherical shape ii) rod shape, investigation of tensile behavior was done with the help UTM of nano plug n play servo control. Fractured surface behavior analyzed by optical microscope. The appropriate dispersion of nanofillers provides more filler surface area accessible for linking with polymer chain, but also restricts the aggregation of filler and the resultant stress concentrator, harmful to the mechanical behavior of composites. However, some challenges, such the fraction of  $\text{Al}_2\text{O}_3$  in composites, size of  $\text{Al}_2\text{O}_3$  NPs as well as the viscosity of the matrix have to be overcome to achieve uniform dispersion of the  $\text{Al}_2\text{O}_3$  NPs in NCs [Kango et al., 2013].

## 2. MATERIALS AND PROCESSING

$\text{Al}_2\text{O}_3$  nanoparticles both type were provided by Sigma Aldrich India. Rod shape particle has 5-10nm diameter &

50nm length, spherical shape has diameter 14-27 nm. Both particles were used for reinforcement with Epoxy Resin. Bisphenol A, Araldite LY556 and Amine Hardener, HY951 by HUNTSMEN. Hybrid composites Epoxy-alumina sample were synthesized by in-situ polymerization procedure.

The epoxy with nanoparticles with required weight fraction sonicated by bath sonicator for one hour. After sonication to evaporate the acetone by hot plate magnetic stirrer and ensure that the temperature not to exceed by 65°C. After whole evaporation of acetone from the mixture. And for degas the epoxy-alumina hybrid mixture was kept in desiccator with vacuum pump under vacuum for 30 minutes to remove any entrapped gases. After that hardener HY951 was added in epoxy resin (ratio of 1:10 by weight epoxy) and gently mixed. The mixture was poured in mold, and cured for 24 hours at room temperature. After curing the nanocomposite sample was taken out of the mould and proceeded to post cure at 100°C for 4 hours in an air circulating oven. Epoxy-alumina nano hybrid all composites sample were prepared for weight fraction of 0.5 wt%, 1 wt%, and 1.5 wt% of  $Al_2O_3$  nano particles of spherical and rod shape.

*Particle size analyzer (PSA)* on a selected weight fraction of nano filler disperse in acetone with the same condition as considered at the time of casting and assume that the dispersion in liquid is same as in matrix and the peak of PSA graph (fig. 1) indicate that the particles are not agglomerated.

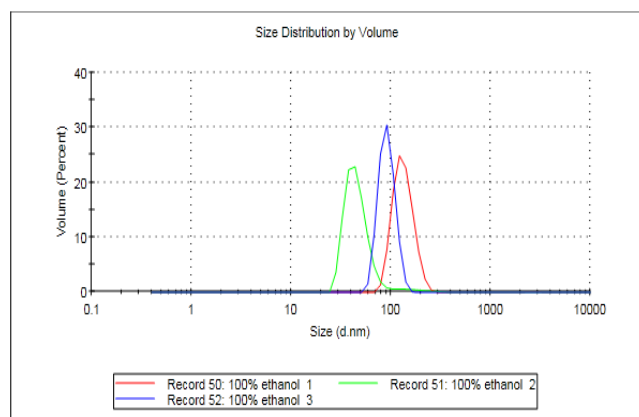


Fig. 1. PSA analysis of 1% weight fraction

### 3. CHARACTERIZATION

Mechanical and optical characterization of composite matrix was examined. For mechanical characterization ASTM Standard D-638 [10] is used. In the current study  $Al_2O_3$  reinforced nanocomposite. Test specimen prepared by mould shaped according to ASTM Standard D-638 (Type-I) dimension are shown in figure 2; having overall length 165 mm, thickness 5 mm, width of narrow section 13

mm, width overall 19 mm, gauge length 50 mm and length of narrow section 57 mm.

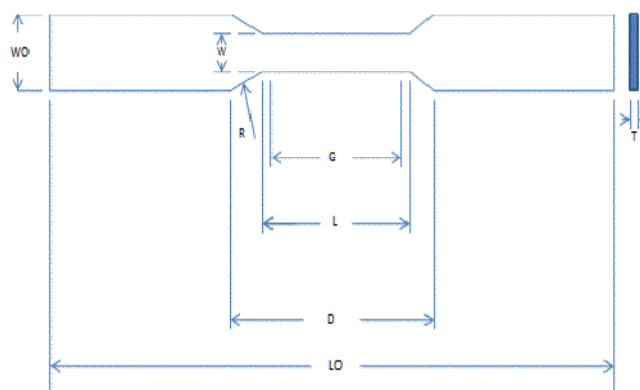


Fig. 2. Specimen dimension.

Fractured surface analyzed by the metzer-m co-axial trinocular research metallurgical optical microscope vision plus-5000 TMM. Tension test were performed at universal testing machine servo hydraulic computerized for 25 kn series of nano "plug'n'play" Biss India. Cross head speed of 5 mm/min. Elastic modulus & tensile strength were determined from result of specimen tested. For each weight percent 4 samples were tested.

### 4. RESULTS AND DISCUSSION

Stress and strain curves produced from tensile testing of epoxy alumina ( $Al_2O_3$ ) nano hybridization composite shown in figure 3. From the figure 3 clearly show higher curve at 1 wt%, further increasing nanoparticles contained curve declined.

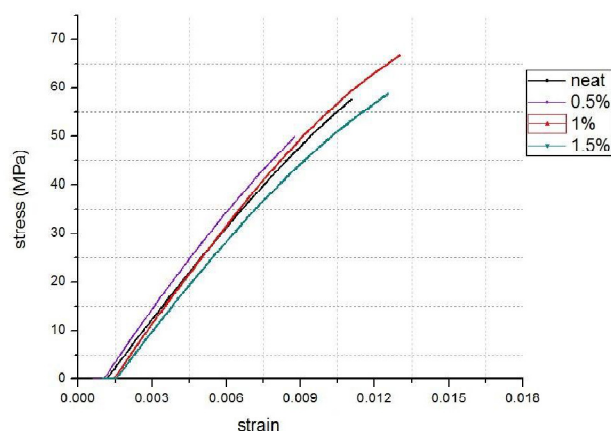
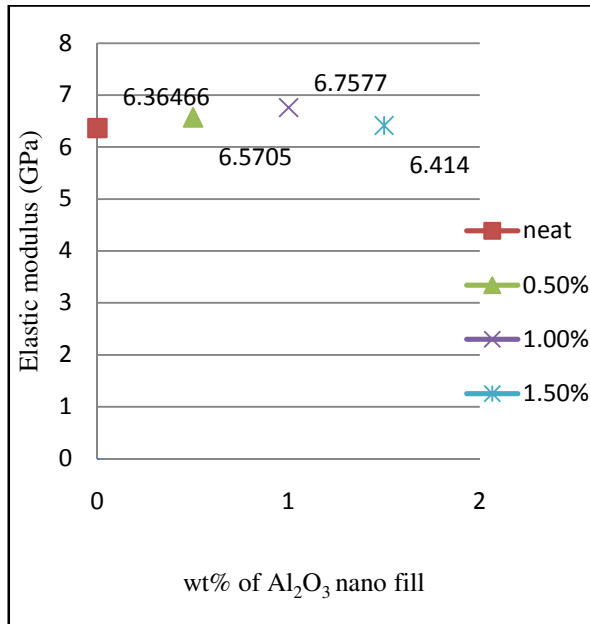
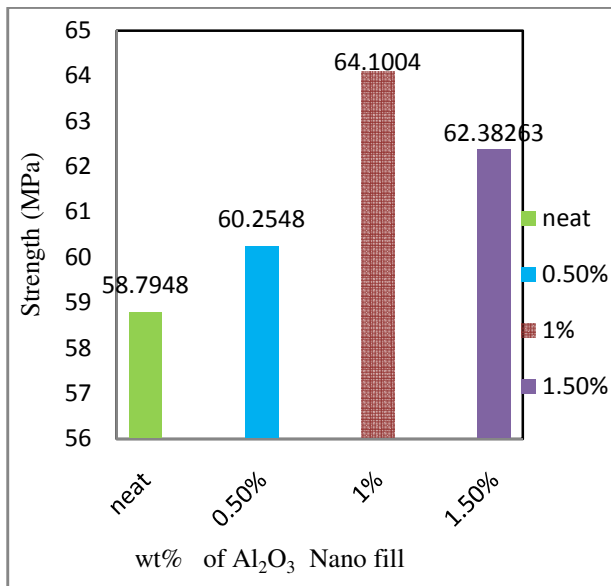


Fig. 3. Stress and strain curve.

Figure 4 shows elastic modulus is higher at 1 wt% and at 1.5 wt% value is decrease. Similarly tensile strength is maximum at 1 wt% further at 1.5 wt% it also decline that shown in figure 5.

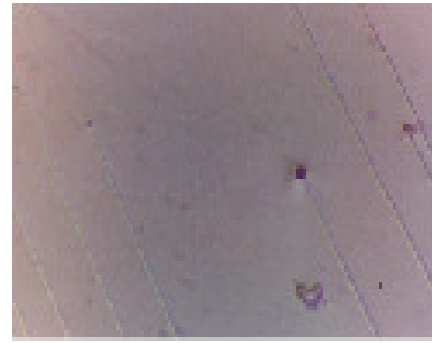


**Fig. 4. Elastic modulus value of every weight fraction.**



**Fig. 5. Average tensile strength at particular weight fraction.**

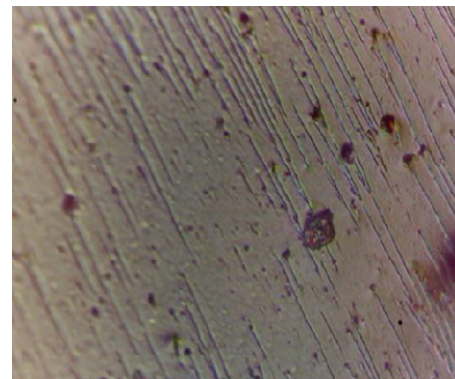
The fracture surface analyzed by optical microscope from which produced image for particular weight fraction as shows figure 6. Figure 6(a) show there is no nanoparticles dispersed so image get clean & fine surface. Further increasing wt% of nano particle increase as well as surface get rough & irregular. Requirement of energy more for split if testing neat epoxy matrix to higher wt% of Al₂O₃nanocomposite. Because energy absorbing by nanoparticles during break. So energy consumption more due to closing traction of particles at higher weight fraction composite.



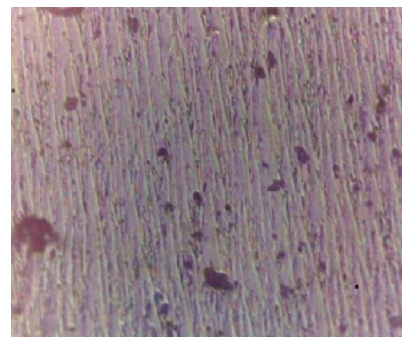
**(a) Neat epoxy.**



**(b) 0.5 wt% of Al₂O₃ hybrid nano particles.**



**(c) 1 wt% of Al₂O₃ hybrid nano particles.**



**(d) 1.5 wt% of Al₂O₃ hybrid nano particles**

**Fig. 6. Optical Microscope fractured surface depiction.**

## 5. CONCLUSIONS

This work shows that successful fabrication of an alumina filled epoxy based polymer nanocomposite with rod and spherical shape alumina particles. This study was focussed on the Synthesis and the characterization of epoxy nanocomposites. Special attention was directed towards reinforcing effects of nanoparticles on the polymer tensile strength. The tensile strength increase and the result are tabulated below.

**TABLE 1: Variation of tensile strength at different weight % of  $Al_2O_3$**

S.No.	Wt %	Tensile strength(MPA)
1	0	58.7948
2	0.5	60.2548
3	1.0	64.1004
4	1.5	62.3826

The decrement of the tensile strength at 1.5wt% can be due to filler agglomeration or de-bonding in matrix material (epoxy) and formation of void due to hard particles.

## ACKNOWLEDGEMENTS

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# Optimization of End Milling Process by Taguchi and ANOVA

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**Abstract:** In this research paper, the attempt is made to experimentally investigate the effect on Al2024-T4 work piece material. The independent process parameters used are cutting speed, feed per tooth, axial depth of cut, radial depth of cut and tool type. The response parameters are surface roughness, cutting force and MRR. Experimentation is performed as per Taguchi L27 Orthogonal Array. A noise factor-hardness of the work piece material is considered to make the experimental design robust. Minimum quantity lubrication (MQL) is used as the latest lubrication system used in manufacturing process. The experimentation is done on CNC flex-mill milling machine. The results of ANOVA revealed the most significant process parameter. The mathematical model is also prepared by regression analysis.

**Keywords:** Al2024-T4 workpiece material, End milling, optimization, Taguchi Method, ANOVA, S/N ratio.

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## 1. INTRODUCTION

Now a day, the fulfillment of customer's satisfaction in terms of low cost, high quality, easily deliverable is a key to stand strongly in the field of manufacturing Market. Quality and productivity are two important but conflicting criteria in any machining operations. In order to ensure high productivity, extent of quality is to be compromised. It is, therefore, essential to optimize quality and productivity simultaneously. Productivity can be interpreted in terms of material removal rate in the machining operation and quality represents satisfactory yield in terms of product characteristics as desired by the customers. Dimensional accuracy, form stability, surface smoothness, fulfillment of functional requirements in prescribed area of application etc. are important quality attributes of the product. Increase in productivity results in reduction in machining time which may result in quality loss. On the contrary, an improvement in quality results in increasing machining time thereby, reducing productivity.

Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth. The axis of rotation of the cutting tool is perpendicular to the direction of feed, either parallel or perpendicular to the machined surface.

An end mill can cut a work piece either vertically, like a drill, or horizontally using the side of the end mill to do the cutting. This horizontal cutting operation imposes heavy lateral forces on the tool and the mill, so both must be rigidly constructed. By making a series of horizontal cuts across the surface of a work piece, the end mill removes

layers of metal at a depth that can be accurately controlled to about one thousands of an inch (.001").

Today many techniques for improving lubricating in machining process are used. In dry machining process the cutting operation done without any lubricant. In wet machining process which is done in most of the industry the lubricant used in continuous basis on large quantity and hence go waste. Hence it will also increase the production time and cost.

One of them is Minimum Quantity of Lubrication (MQL) that vegetable oil mixed with air and spray to machining zone under certain flow rate and pressure air. MQL plays a significant role in manufacturing processes and improved the machining efficiency such as high surface quality, lower tool wear and etc.

## 2. TAGUCHI METHOD

Taguchi method is widely used as a powerful tool for designing high-quality system during research and development so that high quality products can be produced in a minimum time and minimum cost. Taguchi parameter design is an important tool for robust design. Two major tools in robust design are,

- Orthogonal arrays, which accommodate many design factors simultaneously.
- Signal to Noise ratio, which measures quality with emphasis on variation.

Taguchi parameter design which provides a systematic procedure that can effectively and efficiently identify the optimum surface roughness, Metal removal rate and cutting

forces in the process control of individual end milling machines. A series of experiment have been carried out in Design of Experiments to investigate the influence of cutting conditions such as cutting speed, feed per tooth, depth of cut on surface finish, Metal removal rate and cutting forces in end milling operation. The milling process is primary controlled by cutting speed, feed and depth of cut. The other factors can be the type of material, the tool type, the kind of operation, tool type, tool material and the cutting conditions. These parameters has a very significant role on considered Responses such as Surface Roughness (Ra), Metal removal rate (MRR) and cutting forces. Many researchers had worked in order to improve those responses. Design of experiments, Taguchi method is being utilized to refine the outcome of the researches being carried out. The most popular methods for optimization are full factorial design, Response surface method, Taguchi method, etc. But Taguchi method is one of the powerful techniques amongst optimization because it takes minimum number of experiments and all relevant possible combination of input parameters those highly influence the output.

Taguchi's approach is totally based on statistical design of experiments, and this can economically satisfy the needs of problem solving and product / process optimization. By applying this technique one can significantly reduce the time required for experimental investigation, as well as to study the influence of individual factors to determine which factor has more influence and which has less. Taguchi's Orthogonal Array (OA) provides a set of experiments with less number of experimental runs. Taguchi's signal-to-noise

ratios (S/N), which is logarithmic functions of desired output; serve as objective functions in the optimization process. This method uses a special design of orthogonal arrays to study the entire parameter space with a minimum number of experiments. In the framework of Taguchi method L27 OA has been used in order to explore the process interrelationships within the experimental frame. Taguchi recommends analyzing the mean response for each run in the inner array and also suggest to analyze variation using an appropriately selected signal to noise ratio (S/N). There are three signals to noise ratios of common interest for optimization of static problem is given by equations 1, 2, 3 respectively.

$$1. \text{ Smaller the better} \\ n_{ij} = -10 \log (1/n \sum_{j=1}^n y_{ij}^2) \quad (1)$$

$$2. \text{ Larger the better} \\ n_{ij} = -10 \log (1/n \sum_{j=1}^n 1/y_{ij}^2) \quad -- (2)$$

$$3. \text{ Nominal-the-better} \\ n_{ij} = -10 \log ((1/n \sum_{j=1}^n y_{ij}^2)) \quad -- (3)$$

Where,  $n_{ij}$  = signal to noise ratio.  $y_{ij}$  = observed value of the  $i$ th experiment at the  $j$ th test.  $n$  = number of

Observation in a trials = Standard deviation. The higher S/N ratio corresponds to a better performance no matter what is the category of the performance characteristics.

In order to adopt KM effectively in SC, some creditable works have provided several barriers of KM adoption in SC (see table I).

**TABLE 1: Summary of literature review and experts Opinion**

Main criteria	Code	Enablers of KM adoption in SC (Sub Criteria)	References
Employee Traits	ET 1	Knowledge exchange and value addition in SC	Kim et al. 2011; Paton and McLaughlin, 2008
	ET 2	Knowledge Capture	Khalfan et al. 2010
	ET 3	Employee Involvement	Shih et al. 2012; Kim et al. 2011
Organizational Strategy	OS 4	Employee training and Education	Blumenberg et al. 2009
	OS 5	Organization Structure	Bandyopadhyay and Pathak, 2007
	OS 6	Top Management Support	Zhao et al. 2012; Aziaz and sparrow, 2011
Organizational Culture	OC 7	Trustworthy teamwork to exchange knowledge within SC	Shih et al. 2012; Samuel et al. 2011;
	OC 8	Communication among the SC members	Shih et al. 2012; Al-Mutawah, Lee and Cheung, 2009;
	OC 9	Ethics and Culture	Wong and Wong, 2011; Hult, Ketchen and Arrfelt, 2007;
Technological Factors	TF 10	Networking Techniques	Hutzschenreuter and Horstkotte, 2010;
	TF 11	Communication and Collaboration techniques	Hutzschenreuter and Horstkotte, 2010;



Main criteria	Code	Enablers of KM adoption in SC (Sub Criteria)	References
	TF 12	Service Exchange	Paton and McLaughlin, 2008
Managerial Factors	MF 13	Decision Knowledge Sharing	Wadhwa et al. 2006
	MF 14	Integration of Knowledge and information flow	Shih et al., 2012; Al-Mutawah, Lee and Cheung, 2009
	MF 15	Employee Empowerment	Samuel et al. 2011; Natti and Ojasalo, 2008

### 3. EXPERIMENTATION AND ANALYSIS

#### 3.1 Experimentaion

The experimentation performed on CNC FLEXMILL machine that has a maximum spindle speed as 4000rpm. A 10mm Carbide end mill tool bit selected for experimentation. The experimental setup is shown in figure1.



Fig. 1.

#### 3.2 MATERIAL SELECTION

Now a days, industries and aerospace demand the kind of material which are light in weight and also have very good strength. In those industries hence, the work piece selected is Al2024. The material has a wide application in broad areas like Hydraulic valve bodies, Nuts, fasteners, rivets, screws, gears & shaft, bolts. For this experimentation the material selected is Aluminum Alloy (Al2024-T4) with the size of 80mm × 80mm × 16mm blocks. The chemical composition and mechanical properties of the work piece materials are shown in table.

TABLE 2: Chemical Composition of Al2024									
Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Tin	Zn
Wt%	90.7-94.7	Max 0.1	3.8-4.9	Max 0.5	1.2-1.8	0.3-0.9	Max 0.5	Max 0.15	

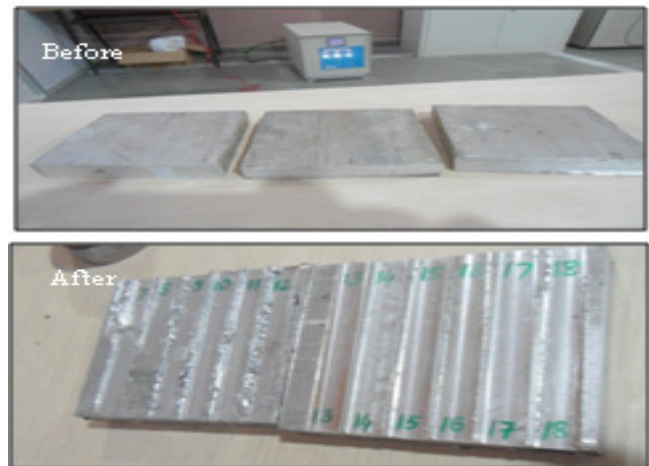


Fig. 2.

#### 3.3 Design of Experiment

The spindle speed, feed and depth of cut were selected as input parameters as listed below in table.

TABLE 3: Cutting parameters

Independent variables	Units	1	2	3
Spindle speed	rpm	1500	1650	1800
Feed	mm/tooth	0.1	0.15	0.2
Axial depth of cut	mm	1	1.5	2
Radial depth of cut	mm	8	10	12
Tool type		HSS	CVD	PVD

Total 27 experiments were carried out with two different conditions that are for wet and mist lubrication by taking noise factor as hardness of material. So material of the work piece will be classified in three categories-low, medium and high hardness material. and another set of experiments will be performed on these to get the optimal value.

The characteristic used in this experiment was the S/N ratio smaller is better, where the low surface roughness and low cutting forces desirable. Also S/N ratio higher is better is desirable for metal removal rate.

### 3.3 Observations



**Fig. 3. Hardness testing**

The experiments performed under various cutting conditions. According to taguchi method orthogonal array OA-27 were selected .Therefore Total 27 experiments performed under every cutting condition.

**TABLE 4: L27 Orthogonal array**

RUN	Cutting Speed (RPM)	Feed (mm/teeth)	Axial Depth of Cut (mm)	Radial Depth of Cut (mm)	Tool diameter (mm)	Tool Material
1	1500	0.1	1	8	8	HSS
2	1500	0.1	1	8	10	CVD
3	1500	0.1	1	8	12	PVD
4	1500	0.15	1.5	10	8	HSS
5	1500	0.15	1.5	10	10	CVD
6	1500	0.15	1.5	10	12	PVD
7	1500	0.2	2	12	8	HSS
8	1500	0.2	2	12	10	CVD
9	1500	0.2	2	12	12	PVD
10	1650	0.1	1.5	12	8	CVD
11	1650	0.1	1.5	12	10	PVD
12	1650	0.1	1.5	12	12	HSS
13	1650	0.15	2	8	8	CVD
14	1650	0.15	2	8	10	PVD
15	1650	0.15	2	8	12	HSS
16	1650	0.2	1	10	8	CVD
17	1650	0.2	1	10	10	PVD



RUN	Cutting Speed (RPM)	Feed (mm/teeth)	Axial Depth of Cut (mm)	Radial Depth of Cut (mm)	Tool diameter (mm)	Tool Material
18	1650	0.2	1	10	12	HSS
19	1800	0.1	2	10	8	PVD
20	1800	0.1	2	10	10	HSS
21	1800	0.1	2	10	12	CVD
22	1800	0.15	1	12	8	PVD
23	1800	0.15	1	12	10	HSS
24	1800	0.15	1	12	12	CVD
25	1800	0.2	1.5	8	8	PVD
26	1800	0.2	1.5	8	10	HSS
27	1800	0.2	1.5	8	12	CVD

#### 4. ANALYSIS

Minitab 17 software was used as it provides an effortless method to create, edit and update graphs. Also it provides a dynamic link between a graph and its worksheet that helps in updating the graph automatically whenever the data is changed.

##### i) For Wet cutting:

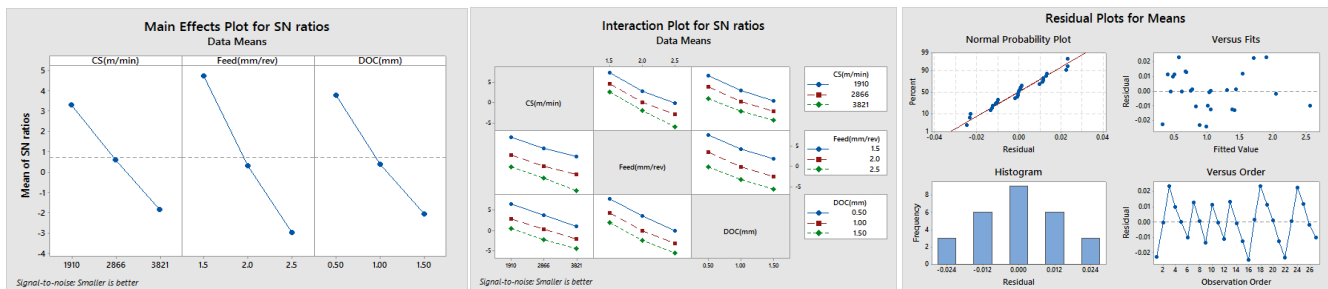
**TABLE 5: ANOVA for Signal to Noise Ratios (Surface Roughness) Smaller is better**

Symbol	Parameter	Degree of Freedom	Sum of Square	F	P
A	Cutting speed (m/min)	2	3.4324	361.81	0.000
B	Feed rate(mm/rev)	2	2.4808	261.49	0.000
C	Axial Depth of cut (mm)	2	5.5487	584.88	0.000
d	Radial Depth of cut (mm)	4	0.0072	0.38	0.818
Error		8	0.0379		
Total		26			

#### 5. RESULTS AND DISCUSSION

##### i) Plots For Surface Roughness :

The main effect plot interaction plot, interaction plot and residual plots are plotted with the help of Minitab software. The graphs are self explanatory and helpful predicting the results. The optimal values are selected from the graph below



**Fig. 4. (a) Main effect plot (b) Interaction plot (c) Residual plot**

ii) Plots For Metal removal rate (MRR)

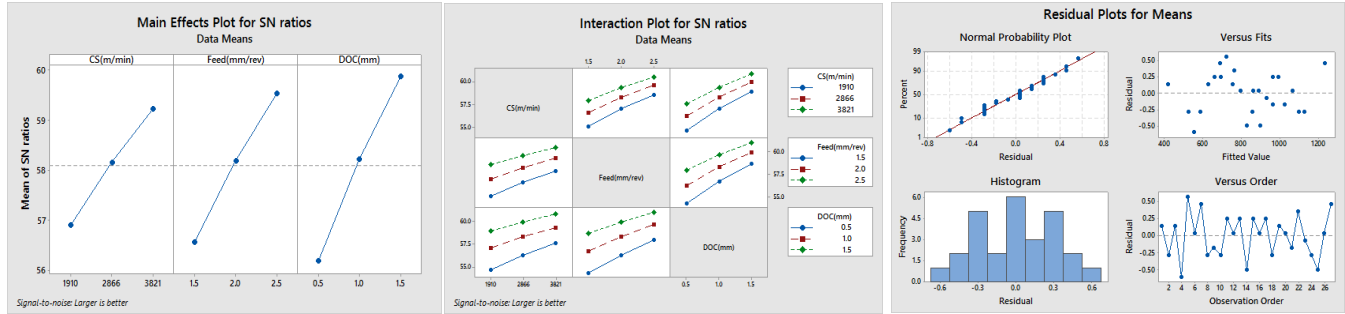


Fig. 5 (a). Main effect plot (b) Interaction plot (c) Residual plot

iii) Plots For Cutting forces

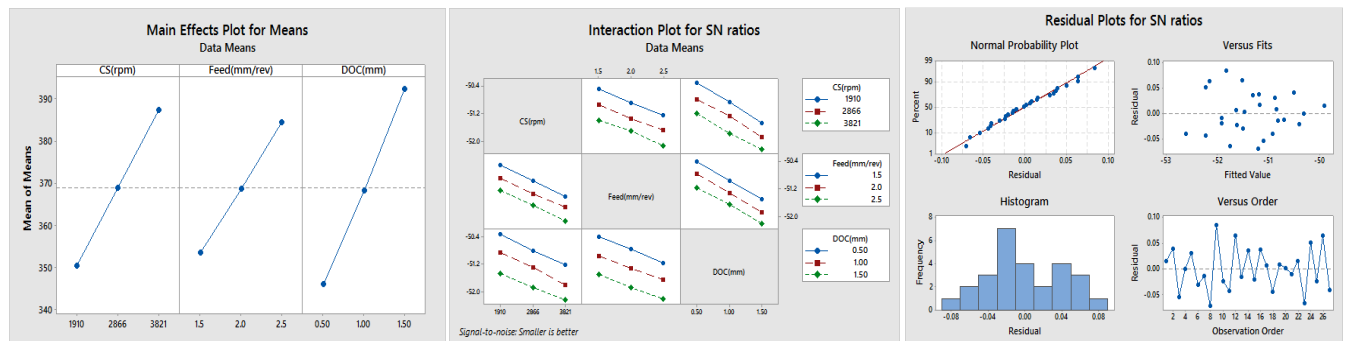


Fig. 6 (a). Main effect plot (b) Interaction plot (c) Residual plot

TABLE 6: Predicted and experimental optimal values

Quality Characteristics	Optimal Level of Process Parameters	Significant process Parameters (at 95% Confidence Level)	Predicted Optimal Value of Quality Characteristics	Experimental value at optimal setting
$Ra(\mu m)$	A1 B1 C1	A B C	0.258 $\mu m$	0.25 $\mu m$
$MRR(mm^3/min)$	A3 B3 C3	A B C	1232.56 $mm^3 / min$	1231.24 $mm^3 / min$
$CF(N)$	A1 B1 C1	A B C	308.416 N	309.91 N

The results were compared under wet and mist conditions for the various outputs surface roughness, metal removal rate and cutting forces. The values are tabulated below

TABLE 7: Comparison between the output

OUT PUT	WET	MIST
SR ( $\mu m$ )	0.302	0.25
MRR ( $mm^3/min$ )	1228.16	1231.24
CF (N)	312.56	309.91

## 6. CONCLUSION

The machining characteristics of Al 2024 have been studied. The primary machining characteristics such as surface roughness, cutting forces and metal removal rate were studied for End milling. From S/N Ratio response table, depth of cut, feed rate and cutting speed are the order of influence of parameters on surface roughness, cutting forces and metal removal rate. The result of ANOVA for surface roughness, depth of cut has the more significant parameter for affecting the surface roughness; cutting speed has the more significant parameter for affecting the cutting forces. Good agreement was shown between the predictive model results and the experimental measurements.

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# Casting Defects Analysis and Optimization of Process Parameters for Sand Casting: A Review

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**Abstract:** Metal casting is a very age old and well established production technique in which molten metal is poured into the mould cavity to get the required shaped metal product. In sand casting method, process of making casting depends upon various factors like mould, gating system, type of metal etc. These distinct factors affect the production quality of casting. Casting method also has importance because it is an economical process and has the ability to produce number of different and complex shaped metal products. For a sound casting, it is required to optimize the casting parameters, for a given geometry of casting, to remove the defects in casting product. In this paper various casting defects and their dependent and independent parameters along with their optimization techniques are studied to know effect of those parameters to rise the casting quality by reducing casting defects. It also focuses on Taguchi Technique and Computer Aided Casting Simulation Technique to improve the productivity of defect free casting.

**Keywords:** Selection of casting parameters, casting defects, Taguchi method, Computer simulation

## 1. INTRODUCTION

As looking towards history traditional casting process is running since 6000 years long and is a basis of the entire mechanical industry. However, it still faces various problems such as difficulty in quality improvement, less production rate, to improve energy efficiency, to reduce material consumption and the question of environmental protection; one of the reasons behind it is complex casting process and lack of theoretical guidance (C.M. Choudhari et al., 2014). Sand casting is one of the most simplest type of casting process and highly used for centuries since it accounts for largest tonnage of production of different types of castings and because of its economical facts and flexibility in production (Manikanda Prasath K. et al., 2014). Casting process has many quality affecting casting process parameters some of which are controllable and some are noise factors. Therefore Taguchi Technique is the good choice for quality improvement in castings. Taguchi's contributions have made the practitioner's work simpler by advocating use of very less number of experimental designs and providing clear understanding of variation nature and economic consequences of quality engineering in the manufacturing sector (S. Guharaja et al., 2006). Dr. Taguchi has introduced several new statistical concepts in the field of quality improvement which have proven to be estimable. Many Japanese manufacturers have improved their product and process quality with a great success. Taguchi has calculate on W.E. Deming's observation that only 15% to the worker and more i.e. 85% of the poor quality is attribute to the manufacturing process, out of which again many researchers has reported that 90% of the

defects are due to incorrect design of Gating and risering system.

### 1.1 Process parameters of Green Sand castings

The process parameters can be listed in five categories as follows:

1. Mould-machine-related parameters
2. Cast-metal-related parameters
3. Green-sand-related parameters
4. Mould-related parameters
5. Shake-out-related parameters

An Ishikawa diagram (cause and effect diagram) was constructed as shown in Fig. 1 to identify the casting process parameters that may influence green sand casting defects (S. Guharaja et al. 2006).

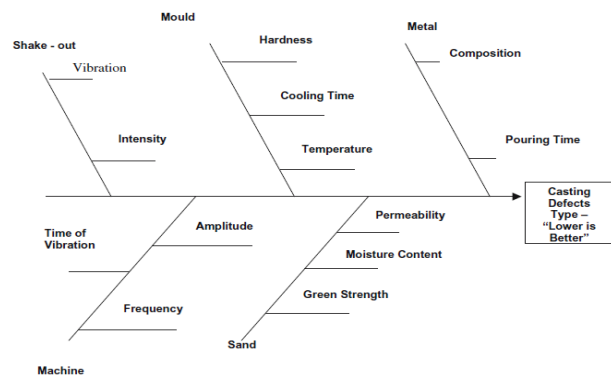


Fig. 1. Cause and effect diagram

## 2. LITERATURE REVIEW OF CASTING DEFECT AND OPTIMIZATION TECHNIQUE

Presently various research work and experiments has been done on several distinct casting parameters for all casting methods. In sand casting the process parameters are classified in following categories as: 1. Machine related parameters 2. Metal related parameters 3. Sand related parameters 4. Mould related parameters 5. Shake-out related parameters, etc. Most percentage of defects are improved by optimizing sand and gating system related parameters.

Zhizhong Sun *et al.* (2008) discussed to optimize the gating system parameters of cylindrical magnesium casting in iron foundry by maximizing signal to noise ratios and minimizing the noise factors using Taguchi method with multiple performance characteristics. They have selected four gating system parameters, namely ingate height, ingate width, runner height, runner width for optimization with consideration of multiple performance characteristics including filling velocity, shrinkage porosity and product yield.

The optimum conditions for the four factors calculated are:

- Ingate width – Level 2 – 50mm
- Ingate height – Level 3 – 50mm
- Runner width – Level 3 – 40mm
- Runner height – Level 2 – 55mm

Although the product yield has decreased by 1.57%, the shrinkage porosity is decreased by 56.57% and the filling velocity is decreased by 58.05% and finally it is concluded that the multiple performance characteristics such as product yield, shrinkage porosity and filling velocity can be simultaneously considered and improved through this optimization technique.

N. W. Rasmussen *et al.* (2002) analyses the importance of design of gating and riser system to secure good casting quality in both Aluminium and Iron castings. Further in discussion it is found that the flow of metal in gating system and the flow of velocity at the ingates to the casting respectively should be as low as possible and the temperature distribution in the casting should be as low as possible and the temperature distribution in the casting should support directional solidification towards of the feeders as much as possible, to get a good casting quality especially to improve yield and which is possible to get by improving gating and feeding system.

Uday A. Dabhade *et al.* (2013) applied Taguchi method to optimize the green sand casting parameters as Moisture content (%), green compression strength (gm/cm²), Permeability Number, Mould Hardness Number for improvement of casting quality by reducing casting defects

like sand drop, bad mould, blow holes, cuts and washes for reducing % rejection in casting products.

Also, for reducing Methoding, Filling, and solidification defects such as shrinkage porosity, hot tears etc, Computer Aided casting simulation technique is used. As a result of final optimization the optimized parameters computed are:

- Moisture content: 4.7%
- Green compression strength: 1400 gm/cm²
- Permeability Number: 140
- Mould Hardness Number: 85

Experimental result obtained using optimized parameters as; % rejection in castings due to sand related defects is reduced from 10% to a maximum up to 3.59%. Also concluded that shrinkage porosity defect, quality and yield of casting can be efficiently improved by Computer assisted casting simulation technique in shortest possible time and without doing actual trials in foundry shop.

C. M. Choudhary *et al.* (2014) discussed about the simulation method of sand casting design using AutoCast-X software for minimizing the casting defects to improve its quality. They mentioned that various casting defects occur because of improper design of feeding system. Hence instead of going for direct experimental way, the attempt is made to compute an optimum feeding system using simulation software. Using AutoCast-X software Mould box design feeder design, Casting solidification, shrinkage porosity and feed optimization is done and on these optimized values experimental result obtained as Quality, feeding yield & feeding efficiency as 99.89%, 84.66%, and 22.82% respectively.

S. Guharaja *et al.* (2006) applied Taguchi method to optimize the process parameters of green sand casting. First of all the cause and effect diagram was constructed to identify the process parameters that may influence green sand casting defects. These parameters are categories as: 1. Mould-machine-related parameters 2. Cast-metal-related parameters 3. Green-sand-related parameters 4. Mould-related parameters 5. Shake-out-related parameters. Out of these the most significant parameters with their optimized values are found to be moisture content (2.6%), Green sand strength (950gm/cm²), permeability number (235), and mould hardness number (80). These optimized values were used in final experimentation and gave result as, improvement in casting yield and reduction in casting defect from 25% to a maximum of 3.25%.

Manikanda Prasath K. *et al.* (2014) reduced the sand related casting defects and improved the effective yield of casting by optimizing the green sand process parameters using Taguchi method and by using Solid cast simulation Software for simulating gating system. The optimum

conditions for the control factors of casting process parameters found to be moisture content (4.5%), Green sand strength (1300gm/cm²), permeability number (200), and mould hardness number (75), Pouring temperature (1400 °C), Sand particle size number (AFS) (53). As a result of optimization they have got reduction in casting defects i.e. from 8.10% to 2.71% and effective yield is improved to 64.30% from 58.5%.

A Kumaravadivel *et al.* (2013) discussed about quality enhancing tool called process window approach (PWA) for quickly optimizing and confirming the quality and robustness of a process setup for any parameters. Then analysis of critical process parameters and interaction among them is carried out using Taguchi method of experimental design. To optimize the result obtained and to make the analysis more precise and cost effective response surface methodology (RSM) is also used. The optimum parameter value found out to be Moisture content (3.6%), Permeability number (120), Loss of Ignition (3.5%), Compression strength (1kg/cm²), Volatile content (2.1%), Vent holes (10), Pouring Time (45 sec), Pouring Temperature (1400°C), Mould pressure (5kg/cm²). Final result of experiment with optimum values found as with 95% confidence interval average defects percent error decreases from 11.8 to 6.44 and when tested by PWA it was a negligible 1.68% of error was confirmed.

### 3. PROBLEM IDENTIFICATION THROUGH LITERATURE STUDY

After detailed literature study, Sand and mould related defects such as sand drop, bad mould, blow holes, cuts and washes, etc and Methoding, Filling and Slidification related defects such as shrinkage porosity, hot tears, etc are found out. Also production profit related factors are found out as low casting yield, low product yield, low effective yield etc.

### 4. DISCUSSION

Many casting industries suffers with the problem of defects formation in casted products like shrinkage porosity, blow holes formation, crack generation, low casting yields etc which causes rejection of castings indirectly affects to the profit of production. To make the production profitable many researchers have found out various casting process related parameters and their optimization techniques and has proved these techniques to be effective and profitable by doing experiments in foundries and got the expected outcome values. Fundamental principles of Taguchi method and Computer Aided Simulation Softwares like AutoCast-X, MAGMASOFT, SOLIDCAST etc are found to be very effective tools in optimizing casting parameters and designing of feeding, moulding and gating system respectively at economic cost.

### 5. CONCLUSION

Casting industry has enormous efficiency and scope in producing various distinct metal products at economic rates. But to have maximum profit and to survive in this competitive market with economic production foundry industry has to overcome the casting defects.

Paper highlights that in green sand casting process, casting products deals with various types of defects. Taguchi method and Computer Aided Simulation technique helps to improve the quality of the product by minimizing casting defects and by designing a good feeding, moulding and gating system to maximize the production.

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# Optimization of Process Parameters in Centerless Grinding Operation Using Central Composite Rotatable Design

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**Abstract:** Surface roughness is one of the most important characteristics in machining process. This paper aims to optimize the surface roughness of machining surface under different cutting conditions such as depth of cut, regulating wheel speed and coolant supply rate using experimental design technique, called central composite design (CCD) and response surface methodology. Second-order linear models were developed using experimental results of a rotatable central composite design, and assessed by means of various statistical tests (ANOVA, Contour plot, Normal probability plot). The ANOVA analysis shows that the quadratic model gives a good prediction of the experimental results. In this study it is observed that the optimal process parameters are 25 micron of depth of cut, 22rpm of regulating wheel speed and 300cc/sec of coolant supply rate and at that optimum condition, the value of optimal surface roughness is 0.647 $\mu$ m.

**Keywords:** Centerless Grinding, Surface Roughness, Optimization

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## 1. INTRODUCTION

Surface roughness is one of the most important requirements in machining process. Roughness consists of surface irregularities which result from the various machining process. Every machining operation leaves characteristic evidence on the machined surface. This evidence in the form of finely spaced micro irregularities left by the cutting tool wear. When tool wear increase, the surface roughness also increases. For optimization of the surface roughness value, identification of cutting parameters is very important. The statistical models were developed to predict the surface roughness. Centerless grinding has been widely used in manufacturing engineering as an important finishing process to achieve high precision surface quality. In Centerless grinding process, there are many parameters such as the tool geometry including the mesh size, wheel sharpness, coarser dressing and other parameters such as effective cooling rate, cutting method, and various cutting conditions including the feed rate, depth of cut and cutting speed affecting the surface roughness Ra. Developing predictive models needed to calculate the optimum cutting conditions for minimum surface roughness is a necessary.

Central composite design is an experimental optimization design techniques, useful in response surface methodology (RSM) which explores the relationships between several explanatory variables and one or more response variables, for building a second order (quadratic) model for the response variable without needing to use a complete three-

level factorial experiment. The CCD design is chosen because it is the most efficient second order design for quantitative factors, and it gives more flexibility in the resolution selection. A set of axial points, experimental runs identical to the centre points except for one factor, which will take on values both below and above the median of the two factorial levels, and typically both outside their range. This paper aims to optimize the surface roughness of machining surface under different cutting conditions such as depth of cut, regulating wheel speed and coolant supply rate using experimental design technique (central composite design).

## 2. LITERATURE REVIEW

Zhang et al. (1995) showed that creep-feed grinding technique improved the productivity effectively and surface quality of component with complex profile. Zarudhi et al. (2000) investigated both experimentally and theoretically the formation mechanism of the surface integrity of alumina by ductile-mode grinding. Mitra et al. (2003) optimized multi-objective of an industrial grinding operation using elitist non-dominated sorting genetic algorithm. Ali et al. (2003) used a fuzzy model for predicting burns in surface grinding of steel. Kwak et al. (2004) applied Taguchi and response surface methodologies for geometric error in surface grinding process. Baskar et al. (2004) applied Ants colony algorithm approach for multi-objective optimization of surface grinding operations. Asokan et al. (2005) optimized surface grinding operations using particle swarm optimization technique. Gopala et al. (2005) developed a

scatter search based optimization approach to optimized the grinding parameters of wheel speed, work piece speed, depth of dressing and lead of dressing using a multi-objective function model with a weighted approach for the surface grinding operations. Krishna et al. (2006) optimized multi-objective of surface grinding operations using scatter search approach for surface roughness. Gopala Krishna (2006) optimized surface grinding operations using a differential evolution approach. Lai et al. (2006) applied a regenerative surface fine grinding methodology to remove grinding defects of traditional operations and to improve the quality of surface flatness.

Shih (2001) applied a new regulating wheel truing method for through-feed Centerless grinding. Dhavlikar et al. (2003) applied Combined Taguchi and dual response method for optimization of a Centerless grinding operation. Kim et al. (2003) described a computer simulation model for investigating a two-dimensional (2-D) rounding mechanism in a Centerless Grinding process. Wu et al. (2004) described the development of a new Centerless grinding technique called the ultrasonic elliptic-vibration shoe Centerless grinding.

Rigas et al. (2000) applied central composite design in a refinery's wastewater treatment by air flotation. Muir et al. (2002) applied central composite design in the optimization of thermal desorption parameters for the trace level determination of the chemical warfare agent chloropicrin. Wsol et al. (2002) used Central composite design as a powerful optimization technique for resolution of enantiomers of the rac-11-dihydrooracin. Tippayawong et al. (2005) optimized the ethanolysis production process of ethylester for use as biodiesel. Ahmadi et al. (2005) applied the central composite design and response surface methodology to the advanced treatment of olive oil processing wastewater using Fenton's per oxidation. Kowalski et al. (2006) modifies the central composite design to allow the estimation of separate models for the characteristic's mean and variances under a split-plot structure. Jaouachi et al. (2007) used central composite design to optimize the performance of the strength of wet spliced yarns after sizing. Angelopoulos et al. (2008) proposed that small, balanced and near rotatable central composite designs reducing the design's size and maintaining the ability to estimate all the model parameters. Shivakumar et al. (2008) optimized the formulation of hydrochloride microcapsules employing central composite design.

### 3. PROPOSED METHODOLOGY

To carry out the whole research work in a systematic way many procedural steps was followed which are,

**Step-1:** To get the suitable output of the all inputs process parameters, the selection of the grinding machine is

important. So, identify a suitable Centerless grinding machine in which the experiment would be carried out.

**Step-2:** The output of Centerless grinding machining is depending on the various input process parameters and also changing rate of the output depends on the range of their inputs. That's why Identify the input-output process parameters and response variables of the above manufacturing process and with their range of values.

**Step-3:** Well making of input-output relationship model with Statistical regression modeling technique, the proper data collect collection from the Centerless grinding machining is so much important. So, Data collected very carefully from the selected grinding operation.

**Step-4:** An empirical model is to be developed with the help of Statistical regression modeling technique to express the complex relationship between input(s), in process parameter(s) and output based on prevailing constraints and assumptions need to be applied. It is imperative that the most appropriate effective model is to be developed for surface response.

**Step-5:** Optimization of the process performance using suitable optimization (single objective) techniques with Central composite rotatable design or robust design or any suitable design experiment technique.

**Step-6:** Our target is to find out the optimal input process parameters for surface roughness. So, identify the optimal process parameters from the statistical model using central composite design technique.

**Step-7:** Model will be tested with various testing method such as ANOVA, Contour plot and normal probability plot and it will be validated in a number of dissimilar situations. Validating in dissimilar situations evaluates the relevance of the testing methods.

**Step-8:** Confirmation experiment and verification of results based on the process optimal parameters. The proposed methodology has been shown in following the flow chart.

### 4. EXPERIMENTATION

First the bright-rod cut into 20 pieces by hacksaw and after that facing and chamfering was done on the 20 pieces. The specimens were taken to run the experiments in the Centerless grinding machine by initiate the value of the factors (depth of cut, regulating wheel speed and coolant supply rate) vary by the design. After the different 20 set of experiment run the specimens was taken for measuring the surface roughness. The study was performed with the use of an experimental design method. According to the central composite design (CCD) a total of 20 experiments were generated including two level factorial design, central points, and star points.



In this study, independent variables consist of Depth of cut, regulating wheel speed and coolant supply. The response

chosen was surface roughness of work piece. Table I shows the experimental design matrix.

**TABLE 1: The experimental design matrix**

Run	Coded variables			
	Depth of cut	Regulating wheel speed	Coolant supply rate	Surface roughness
1	20	22	300	0.60
2	25	22	300	0.65
3	20	26	300	0.59
4	25	26	300	0.54
5	20	22	500	0.54
6	25	22	500	0.56
7	20	26	500	0.58
8	25	26	500	0.57
9	18.3	24	400	0.68
10	26.7	24	400	0.63
11	22.5	20.6	400	0.60
12	22.5	27.4	400	0.64
13	22.5	24	231.8	0.60
14	22.5	24	568.7	0.68
15	22.5	24	400	0.66
16	22.5	24	400	0.67
17	22.5	24	400	0.65
18	22.5	24	400	0.64
19	22.5	24	400	0.63
20	22.5	24	400	0.66

## 5. RESULTS AND DISCUSSION

Analysis of variance (ANOVA) is the statistical analysis used to check the significance of the equation with the experimental data. This analysis included the Fisher's  $F$ -test (overall model significance), its associated probability  $p$  ( $F$ ), correlation coefficient  $R$ , determination coefficient  $R^2$  which measures the goodness of fit of regression model. It also includes the Student's  $t$ -value for the estimated coefficient and associated probabilities  $p(t)$ . For each

variable, the quadratic models were represented as contour plots (2D). The optimal combination was determined from contour plot. The Minitab software was used to generate design, regression analysis, and plot abstention and it also is used to draw graph residual vs. actual value and residual vs. predicted value. ANOVA for surface roughness Selectivity and Multiple regression result and significance of regression coefficient for the selectivity of surface roughness table shown in Table II and table III respectably.

**TABLE 2: Multiple regression result and significance of regression coefficient for the selectivity of surface roughness**

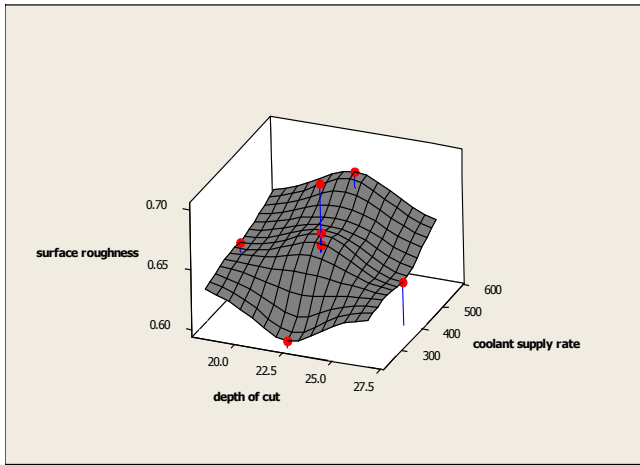
Parameter	Term	Coefficient	SE Coefficient	t-value	p-value
$B_0$		-0.022372	2.18102	-0.010	0.992
$B_1$	$X_1$	0.073831	0.08907	0.829	0.422
$B_2$	$X_2$	0.030552	0.08679	0.352	0.730
$B_3$	$X_3$	-0.002659	0.00264	-1.007	0.332
$B_{12}$	$X_1 X_2$	-0.003250	0.00351	-0.925	0.372
$B_{13}$	$X_2 X_3$	0.000005	0.00007	0.071	0.944
$B_{23}$	$X_1 X_3$	0.000106	0.00009	1.209	0.248
$R$	0.4006				
$R^2$	0.1605				

**TABLE 3: ANOVA for surface roughness Selectivity**

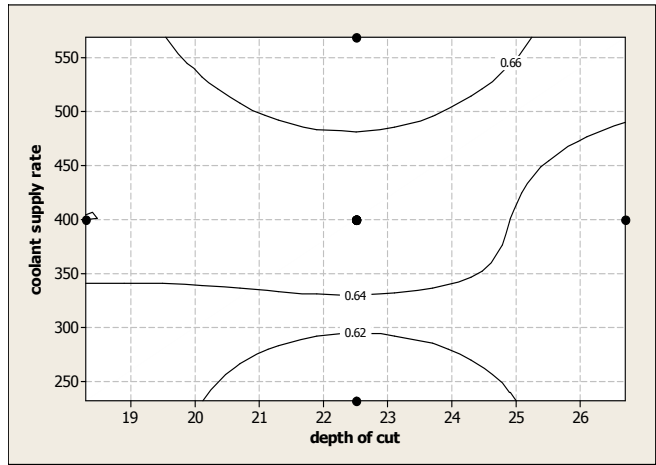
	SS	DOF	MS	F _{value}	F _{value 0.05}	R ²
SS regression	0.006141	6	0.001024	0.41	0.64	0.1605
S.S. error	0.032114	13	0.00247			
S.S. total	0.038255	19				

From Figure 1, the graph shows lowest values of surface roughness at depth of cut 25mm and coolant supply 300cc/sec. (when fixed the regulating wheel speed 24 rpm). From Figure 2, the graph shows the lowest values of surface roughness at depth of cut 25mm and regulating wheel speed 22 rpm (when fixed the Coolant supply 400cc/sec). Similarly, graphical result shows the lowest

values of surface roughness at regulating wheel speed 26.2 rpm and coolant supply rate 470 cc/sec (when fixed the depth of cut 22.5mm). The most appropriate value of the factors from the models is 25mm depth of cut, 22rpm of regulating wheel speed, and 300cc/sec of coolant supply which give the surface roughness equal to 0.649 micron.

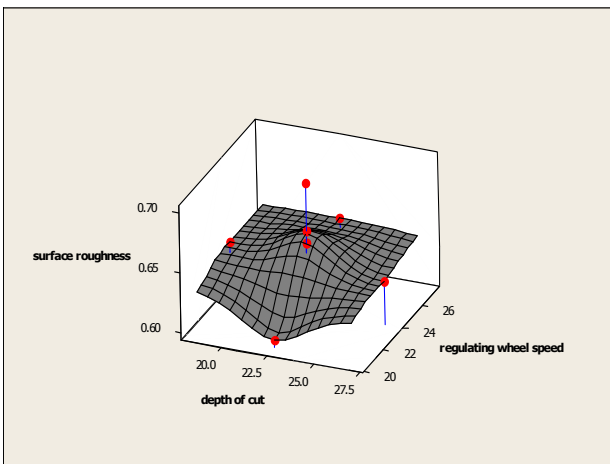


(a)

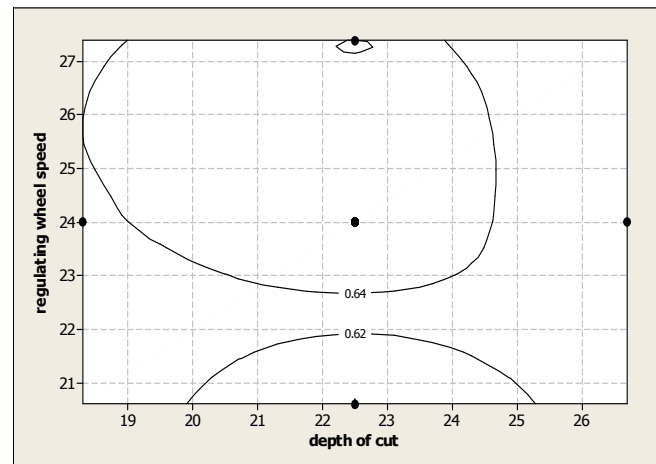


(b)

**Fig. 1. Shows the Response surface (a) and Contour plot (b) for surface roughness a function of Depth of cut and coolant supply rate (at regulating wheel speed 24 rpm)**



(a)



(b)

**Fig. 2. Shows the Response surface (a) and Contour plot (b) for surface roughness as a function of Depth of cut and regulating wheel speed (at coolant supply rate 400cm/sec)**

## 6. CONCLUSION

In this study, Central composite design has been applied for optimal setting of the process parameters in Centerless grinding operation for surface roughness. Central composite coupled with response surface methodology generate a mathematical model to determine the correlation between the response factor and independent variables. ANOVA analysis is used to check the adequacy of the model predicted and the experimental results. Surface roughness obtained from experiment can be explained by the second order polynomial model and the ANOVA result reveal that model predicts the experimental range studied adequately. The results of this study revealed that the surface roughness are influenced by the process parameter i.e. depth of cut, regulating wheel speed and coolant supply rate. According to the contour plots obtained from response surface methodology the fitted surface has a maximum point at the experimental range studied. From the combination of central composite design and different tests, it's observed that the optimal setting of the process parameters at the value of depth of cut, regulating wheel speed and coolant supply rate was 25micron, 22rpm and 300cc/sec respectively and the optimal value of surface roughness for that optimal setting of the process parameters was 0.647 $\mu$ m. The present study is done with consider Central Composite Rotatable Design. Some other type of RSM like BBD, SCD etc. should be applied to compare the results. Some other operation technology like GA, Taguchi Method etc. may be applied to verify the result.

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# Recent Developments in Additive Manufacturing - A Comprehensive Review

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**Abstract:** Additive manufacturing (AM) is one of the emergent techniques in manufacturing realm. The technique finds widespread application globally in modelling and manufacturing the complex shaped products. Aerospace, medical, biomedical, power industries are essentially using the components made from the principles of AM. Although from the literature available an appreciable amount of research work can be found, however, still this is a topic of mass research. Keeping in view of the future potential of AM, the present article presents a comprehensive review summarising of the various aspects related to AM. The content and summary of the present article may provide the first-hand collective information related to the development and challenges of AM.

**Keywords:** additive manufacturing, 3-D printing, recent development.

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## 1. INTRODUCTION

Nowadays the main bearer of radical changes in business models and ecosystems are disruptive technologies. Such technologies in association with the digital technologies led to substantial revamp of the industrial scenario. Digital technologies have made dramatic changes in compliance of the present industries. Due to digitalisation, a trend of 'dematerialisation' has attained a wide acceptance in the present industrial practice. With the growing competition amongst the industries globally, they are thrusting to endeavour to minimise the capital cost, running cost, overhead cost and the lead time. Therefore, in near future role of latest and advanced manufacturing technologies become essential to sustain in the competitive global market.

Manufacturing methods are classified as Additive, Zero and Subtractive process depending on the material used. Out of these, additive manufacturing is one of the emerging and widely applied in the present industrial practices. Some of the additive manufacturing processes are stereo-lithography, inkjet printing and selective laser sintering. Casting and forming come under zero manufacturing process as they involve shifting of metal in a controlled way to get the required shape and size of the product. Subtractive manufacturing processes are conventional machining processes for instance turning, drilling, milling etc. Additive and subtractive manufacturing are also called as bottom up and top down respectively. In other words, additive manufacturing is also known as additive layer manufacturing or 3D printing. It creates the product incrementally by adding thin layers to build up the model from two dimensions to their desired three-dimensional forms (Yampolskiy et al., 2017). Additive manufacturing has several economical and technical advantages as

compared to traditional manufacturing techniques. Objects that are manufactured by additive manufacturing can be used anywhere throughout the product life cycle, from pre-production to full-scale production. Today this technology is already extensively used in the footwear, jewellery, architecture, industrial design, automotive and medical industries (Ruiz-Morales et al., 2017). According to Yampolskiy et al., 2017, the additive manufacturing market potential is near \$230 billion and expected to be around \$550 billion by 2025. According to National Institute of Standards and Technology (NIST), it covers around 50% of the market potential between 2031 and 2038 and \$50 billion in revenue between 2029 and 2031 (Yampolskiy et al., 2017). The major benefits of additive manufacturing are complexity for free, supply chain simplification, distributed manufacturing, functional integration, part consolidation, efficient use of materials and functionally graded materials (Vaneker, 2017).

The challenges linked to additive manufacturing are a lack of standards and procedures, design uncertainty and ambiguity, and issues about the preservation of the intellectual property of digital models. Additionally, lack of control over the processing and complexities enhances the challenges of AM. The availability of AM materials are limited, and software capabilities are not enough to reach full additive manufacturing capabilities of models. The high cost of additive manufacturing machines and materials, high surface roughness in additive manufacturing produced products and removal of support structures and few equally important challenges in AM system (Vaneker, 2017).

Additive Manufacturing processes are used to manufacture components by creating successive cross-sectional layers of the specific component. Firstly, a three dimensional solid model with the help of suitable modelling software is

prepared. Afterwards, the generated CAD file of the solid model gets imported into the corresponding STL file which is eventually used layer by layer material deposition resulting in the final product. Each layer is created using the selective deposition of material to form a printed primitive. Shortly, non-layer based additive manufacturing processes and generation of their tool path is an emerging area of research in the field of advancement in additive manufacturing technology.

The rapid prototyping is one of the segments of additive manufacturing which is very common in modelling of complex parts. Rapid prototyping (RP) primarily focussed on usages of different polymers. However, ceramics, metals

and composites are also used in the latest form of rapid prototyping. Composites are used in Rapid prototyping not only to create the desired product but also to facilitate the process. There are some Rapid Prototyping techniques in trend, but only some of them are used for the production of composites. Laser Engineered Net Shaping, Selective Laser Sintering/Melting, Stereo-lithography and Laminated Object Manufacturing are important processes used in fabricating various composites. Three-dimensional printing, fused deposition modelling and ultrasonic consolidation are some examples of processes using advanced engineering materials (Matta et al., 2015). The schematic of steps of Rapid prototyping is shown in Figure 1.

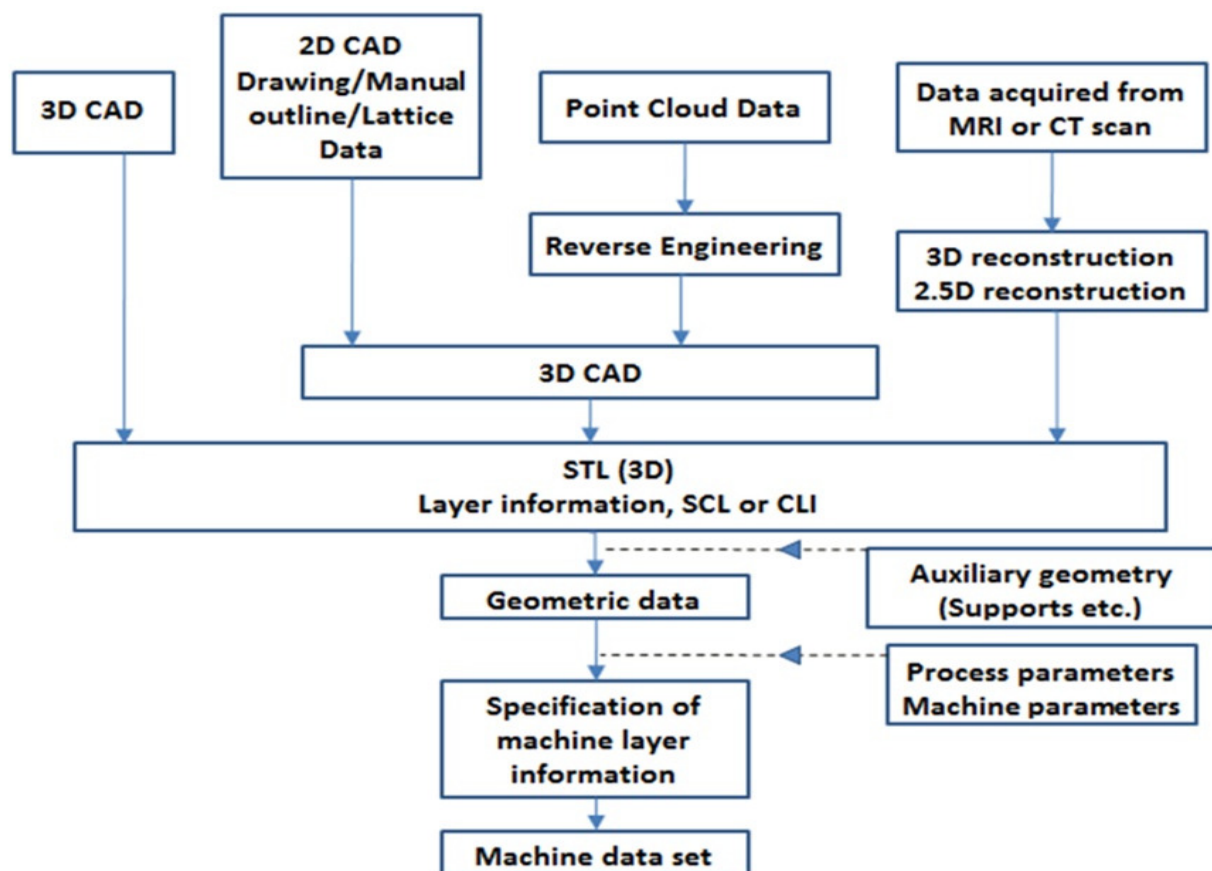


Fig. 1. Schematic of steps of Rapid prototyping

The steps in rapid prototyping are:

- i. A component model is created using the platform of either a computer aided design or computer aided manufacturing system. The CAD model must be represented as closed surfaces that essentially present an enclosed volume specifying the information about the outside, inside and the boundary of the component model. All horizontal cross-sections are necessarily represented by closed curves which are mandatory in making a solid object using rapid prototyping.
- ii. The solid model to be manufactured is then converted into the StereoLithography - STL file format which creates using three dimensional systems. The STL file format approaches the model surfaces by polygons.

- iii. A computer program considers an STL file that defines the model to be prepared and slices the model into various cross-sections. Further, these thin laminations are glued together with adhesives to form a three-dimensional model.

The Rapidprototyping combined diagram in Figure 2 which depicts these four key aspects of Rapid Prototyping. Figure depicts photographic images of the few products made using rapid prototyping at National Institute of Technology Delhi using CubePro 3D printers.

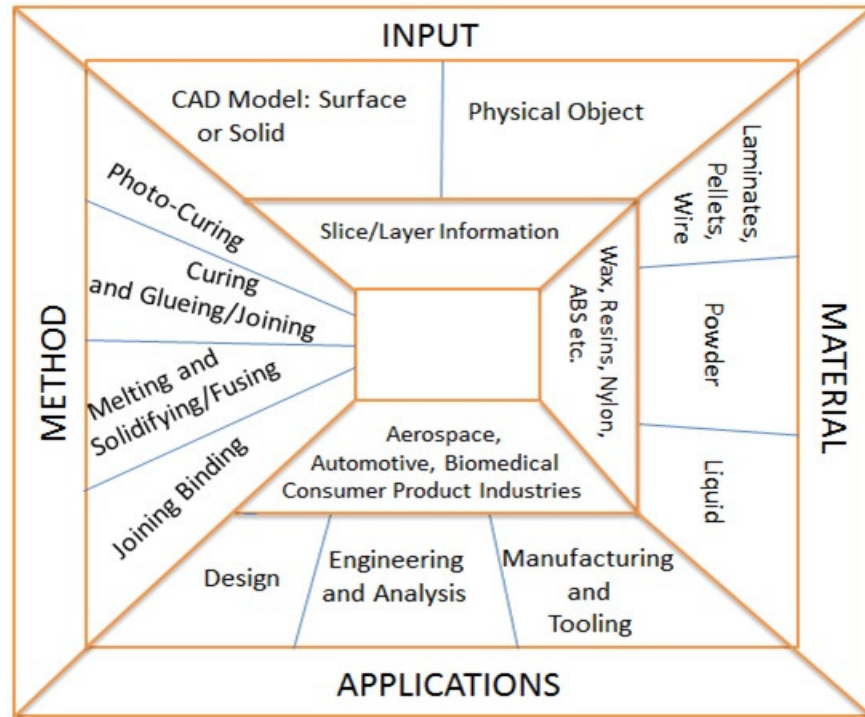


Fig. 2. Schematic depicting the Input, material, applications and method aspects of AM (Chua et al., 2003)

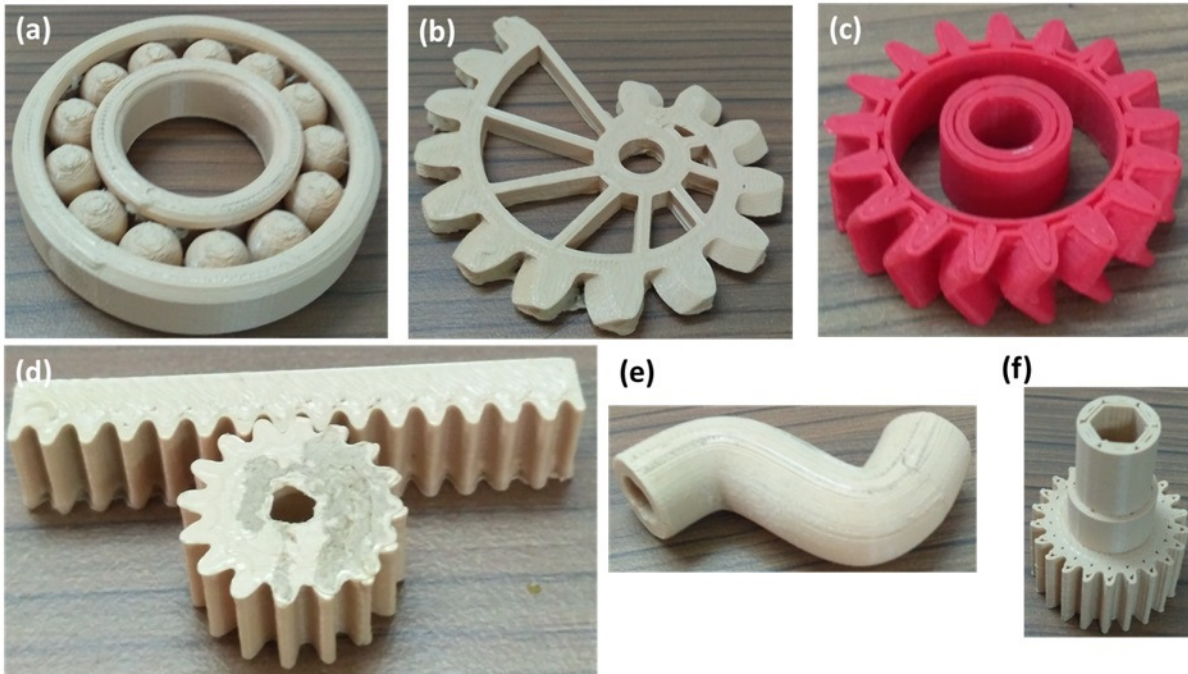


Fig. 3. Photographic images of the few products

**TABLE 1: Detail of all rapid prototyping process information (Gao et al., 2015).**

Categories	Technologies	Printed "Ink"	Power Source	Strengths / Downsides
Material extrusion	Fused deposition modelling	Thermoplastics, ceramic-slurries, metal pastes	Thermal energy	• Inexpensive extrusion machine    • Multi-material printing    • Limited part resolution    • Poor surface finish
	Contour Crafting			
Powder Bed Fusion	Selective Laser Sintering (SLS)	Polyamides/polymer	High powered laser beam	• High accuracy and details    • Fully dense parts    • High specific strength and stiffness    • Powder handling and recycling    • Support and anchor structure
	Direct Metal Laser Sintering (DMLS)	Atomised metalpowder(17-4PH stainless steel, cobalt chromium, titanium Ti6Al-4V), ceramic powder		
	Selective Laser Melting (SLM)			
	Electron Beam Melting (EBM)		Electron beam	
Vat photopolymerization	Stereo-Lithography (SLA)	Photo-Polymer, Ceramics (Alumina, Zirconia, PZT)	Ultraviolet Laser	• High building speed    • Good part resolution    • Overcuring, scanned line shape    • High cost for supplies and materials
Material Jetting	Polyjet or Inkjet Printing	Photopolymer, Wax	Thermal Energy	• Multi-material printing    • High surface finish    • Low strength material
Binder Jetting	Indirect Inkjet Printing (Binder 3DP)	Polymer Powder (Plaster, Resin), Ceramic Powder, Metal Powder	Thermal Energy	• Full-color objects printing    • Require infiltration during processing    • Wide material selection    • High porosities on finished parts
Sheet Lamination	Laminated Object Manufacturing (LOM)	Plastic Film, Metallic Sheet, Ceramic Tape	Laser Beam	• High surface finish    • Low material, machine, process cost    • Describing issues
Directed Energy Deposition	Laser Engineered Net Shaping(LENS) and Electronic Beam Welding (EBW)	Molten Metal Powder	Laser Beam	• Repair of damaged/worn parts    • Functionally graded material printing    • Require post-processing machine



## 2. SUMMARY OF FEW IMPORTANT ARTICLES

**TABLE 2: Summary of the contribution of few important articles related to additive manufacturing.**

Author and year	Technique used	Purpose	Remarks
Ruiz-Morales et al. (2017)	3D Printing	Reviewing previous studies related to developing 3D printing technologies for the fabrication of functional parts applications	Application of 3D printing technologies for the fabrication of functional components is an almost unexplored field due to their elevated complexity from the materials and functional points of view. Use of 3D printing technologies for the fabrication of these devices is also of special interest due to the strong manufacturing limitations of ceramics or composites.
Vaneker (2017)	AM	Design for Additive manufacturing Methodologies are presented and linked to commercial purpose	Presented a new design strategy from a product life cycle viewpoint and a product level for additive manufacturing based product development. Proposed a set of characteristics which define the product window in producing parts with additive manufacturing without redesign.
Levy et al. (2017)	3D Printing	Designed TiC/steel composites with tailored gradient of properties using thermodynamic predictions and fabricated complex-shaped parts	This approach opens the door for advanced applications in tooling, wear, aerospace, ballistic and other fields. Due to the impressive geometrical versatility of the printed parts, infiltration-oriented profile and highly economical operation, binder jetting was used for fabricating graded complex-shaped TiC parts.
Bhushan and Caspers (2017)	3D printing	Review of various manufacturing methods is presented and selected features are compared	An overview of various methods and selected features achievable with commercial printers are presented. SLA and inkjet technology provide microscopic feature sizes and were used to fabricate samples. Printer specifications by manufacturers should be taken critically.
Yampolskiy et al. (2017)	3D printing	Mapped land space of attack with 3D printers that could produce physical impacts	In this paper relationship between taxonomies are discussed. Finally, weaponisation capabilities of 3D printers are characterized.
Gao et al. (2015)	AM	Status, challenges, and future of additive manufacturing in engineering	AM technologies can help in customization of products by directly involving customers in the design stage. However, such technologies are at a nascent stage due to the cumbersomeness associated with design and printing software.
Nelaturi and Shapiro (2015)	AM	Representation and analysis of Additively Manufactured parts	They show that as-manufactured shapes may be represented in terms of the convolution operation to capture the additive deposition of material, measure the conformance to nominal geometry in terms of overlap volume, and model uncertainties involved in material flow.
Frazier (2014)	Metal AM	AM, direct digital manufacturing, free-form fabrication are emerging manufacturing technology explained	They provided a broad contextual overview of metallic AM. They also talked about the potential to revolutionise the global parts manufacturing and logistics landscape by enabling distributed manufacturing and the productions of parts on demand. Highlighted the potential to reduce associated cost, total power requirement and carbon footprint.
Conner et al. (2014)	3D printing	Creating a map of additive manufacturing products and services	A geometric complexity factor developed for cast parts is modified for a more general application. Also considered the implications for product development and manufacturing business approaches.
Kruth et al. (1998)	RP and AM	Progress in Additive Manufacturing and Rapid Prototyping	Summarise one decade of research and developments in rapid prototyping starting with surveying some general economic and technological trends and covers the details on a process-by-process basis.

### 3. SUMMARY OF THE REVIEW

The present work is an attempt to summarise the worthy work related to the additive manufacturing. It covers the essence of additive manufacturing and also highlights the associated challenges that can provide an opportunity for the future researchers to mitigate those. Nowadays, additive manufacturing techniques find multi-sectorial application despite the fact of the high cost involved. There is an urgent need to address the issues of variation in the product hardness, strength, elasticity, reflective index and other physical properties while manufacturing using additive manufacturing techniques. There lies tremendous potential in bringing these technologies to the mass application through a reduction in incurred costs and overcoming the inherent challenges. Meeting the dimensional accuracy and resolution requirement appears to be another equally important area. There needs to look into more vigilantly in CAD model, pre-processing, build prototype and post-processing.

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# Parametric Optimization of Electrochemical Spark Micromachining for Micro-Hole Fabrication

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**Abstract:** The electrochemical spark micro-machining process looks best with greater utility and efficiency in the modern field of the micro-processing industry. The electrochemical spark micromachining process is involved to generate micro channel as well as a curve profile on glass and other nonconductive materials. A mathematical model is developed between the machining rate and various input parameters. The important input variable which affects the machining rate are voltage, inter-electrode gap, and electrolyte concentration. In this process two copper electrodes are used as a tool material and glass is used as a work piece. Mathematical model is developed by Response surface methodology and the analysis of Variance (ANOVA) was carried out to find out the adequacy of the developed models. It is observed from the model that the important process parameters are voltage and concentration which affects the spark intensity. With increasing the spark intensity machining rate will also increase.

**Keywords:** ECSM, MRR, RSM, ANOVA

## 1. INTRODUCTION

The electrochemical spark machining (ECSM) is considered a new hybrid technique used for machining of conductive and non-conductive materials, i.e. silicon, glass, ceramics, composites, etc. Since the actual process of the ECSM is not yet fully understood, the quality features of the machined part represent new challenges in the processing of complex shapes. If a voltage is applied beyond the critical value the discharge begins between the electrode and the surrounding electrolyte, which is called electrochemical discharge. This discharge energy is used for the work piece processing. By regulating the spark intensity machining rate can be controlled.

## 2. EXPERIMENTAL SETUP

The electrochemical spark machining (ECSM) is considered a new hybrid technique used for machining of conductive and non-conductive materials, i.e. silicon, glass, ceramics, composites, etc. Since the actual process of the ECSM is not yet fully understood, the quality features of the machined part represent new challenges in the processing of complex shapes. If a voltage is applied beyond the critical value the discharge begins between the electrode and the surrounding electrolyte, which is called electrochemical discharge. This discharge energy is used for the work piece processing. By regulating the spark intensity machining rate can be controlled.



Fig. 1. Schematic diagram of ECSM



**Fig. 2. Electrochemical spark machined specimen**

### 3. PLANNING OF EXPERIMENT AND DATA ANALYSIS

Performance of ECSM is evaluated by measuring MRR and surface finish obtained during the machining process. Material removal rate basically depends on various parameters. The important parameters which affect the performance are electrolyte concentration, applied voltage, inter-electrode gap. Machining is done on Borosilicate glass having a thickness of 0.5 was designed on the basis of response surface methodology (RSM) for performance evaluation. The material removal rate is calculated for micro-hole fabrication on a copper sheet. Each of these parameters varies in three levels, as shown in the Table I.

**TABLE 1: Process parameter and levels**

Level	Voltage(v)	Concentration (gram/liter)	Electrode gap (cm.)
1	150	30	14
2	180	35	16
3	210	40	18

**TABLE 2: Shows the optimum value of parameter which maximize the machining rate. Table II shows the MRR obtained by the combination of different set of experiment.**

Variable	Optimum Value
Voltage	210V
Electrolyte Concentration	40gram/l
Inter-Electrode gape	14cm

The calculation of material removal rate

$$\text{MRR} = \frac{[\text{Initial Wight of work piece}-\text{final weight of work piece}]}{\text{Time (min.)}}$$

**TABLE 3: Response analysis**

S. N	Voltage (v)	Concentration (gm/l)	Inter electrode GAP(cm)	MRR (gm/min)
1	180	40	14	0.011110
2	180	30	18	0.008330
3	150	40	16	0.006520
4	210	35	14	0.021110
5	180	35	16	0.016250
6	210	35	18	0.017850
7	180	35	16	0.020100
8	150	35	14	0.015120
9	210	30	16	0.018181
10	150	30	16	0.005120
11	180	35	16	0.017120
12	210	40	16	0.020830
13	180	30	14	0.008900
14	180	40	18	0.010770
15	150	35	18	0.007650

### 4. EXPERIMENTAL ANALYSIS OF THE RESPONSE SURFACE METHODOLOGY (RSM) BASED MODELING

The response surface methodology is a useful tool for finding the relationship between various process parameters and the response so as to explore the effect of these parameters on the response criteria of the machining process. The objective of the response surface methodology is to develop the mathematical link between the responses and predominant machining parameters. The general second order polynomial response surface mathematical model can be considered to evaluate the parametric influences on the various machining criteria as follows

$$\begin{aligned} \text{MRR} = & -0.320 + 0.001024 \text{ voltage} + 0.00555 \text{ concentration} \\ & + 0.01506 \text{ electrode gap} \\ & - 0.000002 \text{ voltage*voltage} - 0.000055 \\ & \text{concentration*concentration} \\ & - 0.000329 \text{ electrode gap*electrode gap} + 0.000001 \\ & \text{voltage*concentration} \\ & - 0.000010 \text{ voltage*electrode gap} - 0.000083 \\ & \text{concentration*electrode gap} \end{aligned}$$

Response Optimization: MRR Parameters

Response	Goal	Lower	Target	Upper
MRR	Maximum	0.0052	0.0211	

TABLE 4

SOURCE	CONTRIBUTION	ADJ SS	ADJ MS	F-VALUE	P-VALUE
Model	91.21%	0.007959	0.000884	5.77	0.034
Linear	61.07%	0.005329	0.001776	11.58	0.011
VOLTAGE	54.66%	0.004769	0.004769	31.10	0.003
CONCENTRATION	2.56%	0.000223	0.000223	1.46	0.282
ELECTRODE GAP	3.86%	0.000336	0.000336	2.19	0.199
Square	28.51%	0.002488	0.000829	5.41	0.050
VOLTAGE*VOLTAGE	0.10%	0.000003	0.000003	0.02	0.891
CONCENTRATION*CONCENTRATION	24.09%	0.002228	0.002228	14.53	0.012
ELECTRODE GAP*ELECTRODE GAP	4.32%	0.000377	0.000377	2.46	0.178
2-Way Interaction	1.63%	0.000142	0.000047	0.31	0.819
VOLTAGE*CONCENTRATION	0.00%	0.000000	0.000000	0.00	0.991
VOLTAGE*ELECTRODE GAP	1.62%	0.000142	0.000142	0.92	0.380
CONCENTRATION*ELECTRODE GAP	0.01%	0.000001	0.000001	0.00	0.956
Error	8.79%	0.000767	0.000153		
Total	100%				

## 5. RESULTS AND DISCUSSION

Mathematical modeling is done using RSM. The important response parameter is MRR whereas voltage, concentration and IEG is considered as an input variable. The material removal rate is calculated in terms of the input variable.

The Fig. 2 shows the relation between material removal rate and the voltage. It is observed that with increasing the voltage MRR increases. Since the intensity of spark depends on the applied voltage with increasing the voltage spark intensity will increase as a result MRR will also increase.

### 5.1 Effect of Voltage on MRR

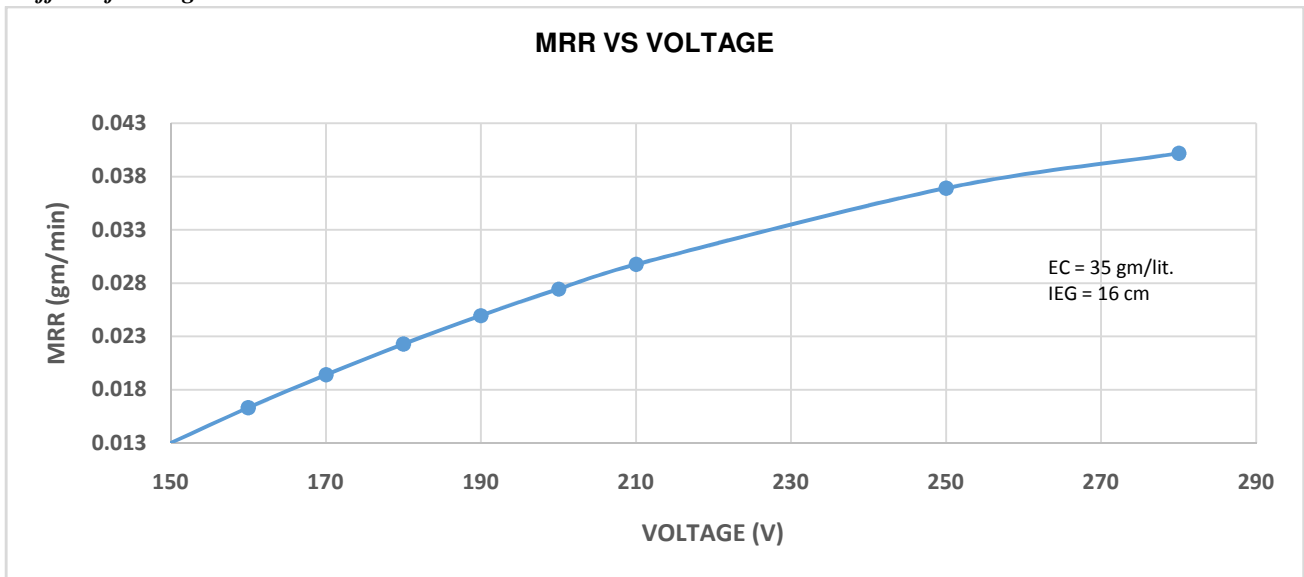


Fig. 3. Variation of MRR variation with voltage

### 5.2 Effect of Inter Electrode Gap on MRR

The Fig. 3 shows the parametric relation between MRR and inter electrode gap. It is observed that Initially MRR increase with the gap since certain gap is required to initiate the spark, but after reaching an optimum value MRR will decrease .With increasing the gap current density and frequency of the spark will decrease.

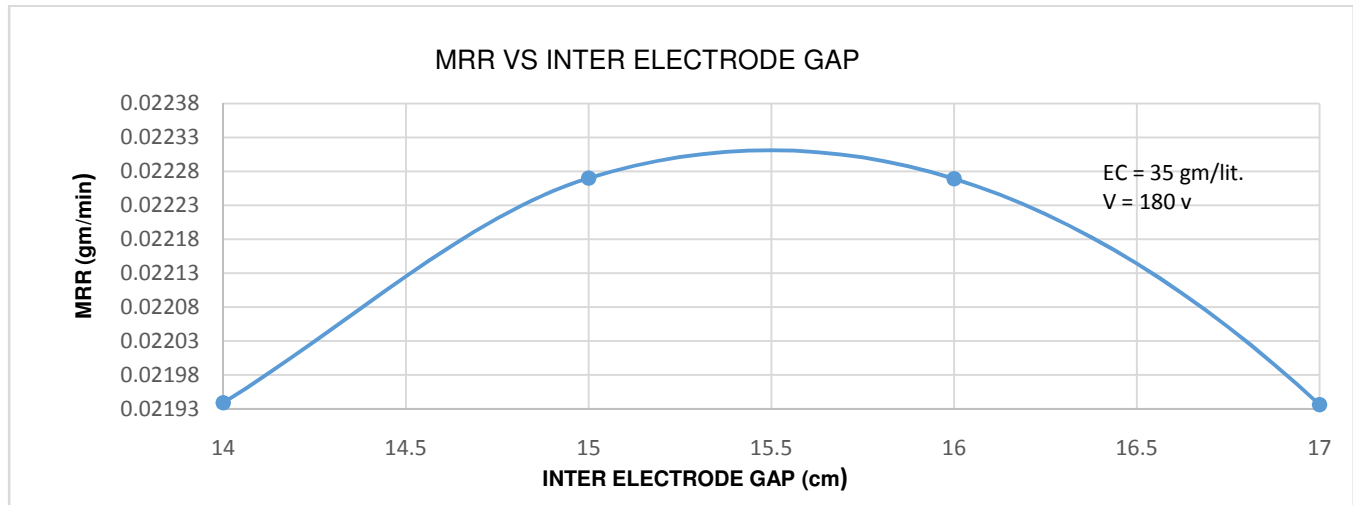


Fig. 4. Schematic diagram of MRR variation with electrode gap

### Effect of Electrolyte Concentration on MRR

The Fig 4 shows the parametric relation between MRR and concentration. Here it is observed that by increasing the concentration MRR increases because of increasing the bubble formation which is mainly responsible for spark formation.

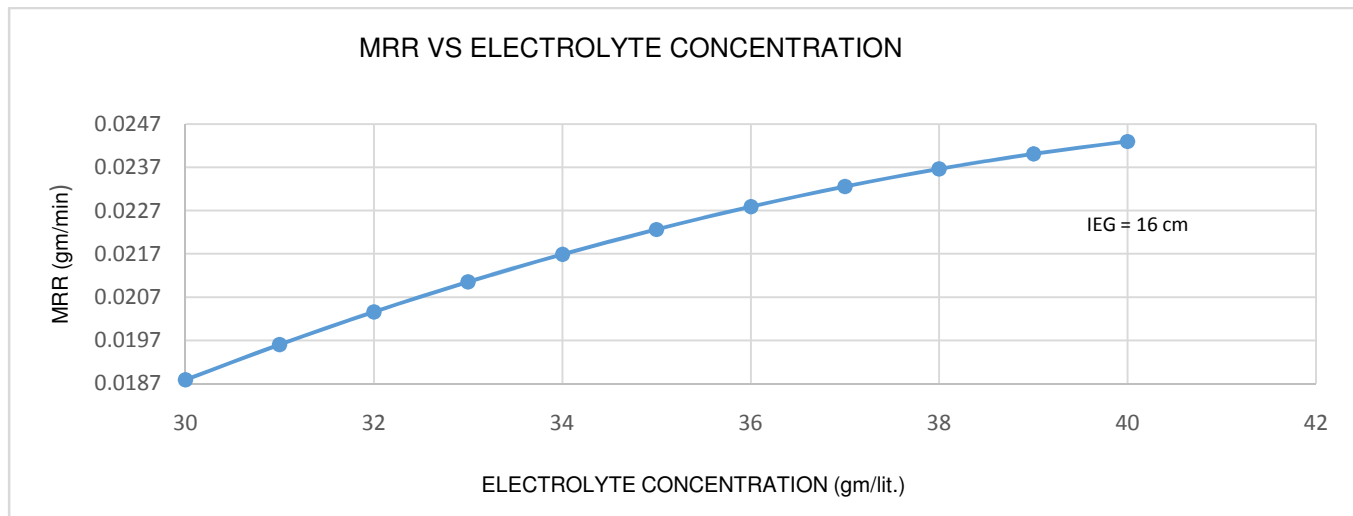


Fig. 5. Schematic diagram of MRR variation with concentration

## 6. DETERMINATION OF OPTIMIZED CONDITION OF MICRO ELECTROCHEMICAL DISCHARGE MACHINE

In this experimental work, the desired goal is to get maximized material removal rate for better machining. MINITAB software is used to get the optimal value of MRR which is 0.0230 g/hr .The optimum value of MRR

can be detected with the combination of the applied voltage of 210 volt, electrolyte concentration of 40 g/l and intermediate gap between electrodes of 15.5 cm.

## 7. CONCLUSIONS

In the present study, an experimental analysis of ECSM for the evaluation of cutting performance is carried out. Experiment is conducted on the glass surface and after

experiments measurement of response parameter is done. The input parameter are Concentration, applied voltage and inter electrode gap. From this study we obtain the optimum values of all these three parameters which provides maximum MRR. The optimum value for voltage is 210V, concentration is 40.0 g/l and inter electrode gap is 15.5. From this study it is discovered that MRR increases with the increase in the applied voltage and the concentration of electrolytes. It was highly controlled with voltage and further concentration and inter electrode gap.

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# Optimization of Electrochemical Discharge Machining Process Parameters Using Genetic Algorithm

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**Abstract:** Process efficiency of any machine can be improved by optimizing effective parameters. This requires identifying and find the value of most effective parameters that lead to desired output leads to lower cost of the manufacturing process. Traditional optimization technic is generally slow in require much processing time. They did not provide accurate value Compared to Genetic Algorithm (GA) Genetic Algorithm is robust, global and can be applied without any recourse to domain-specific heuristics. So this Nobel characteristic GA is used to optimization of Electro-Chemical Discharge Machining (ECDM) process. Mathematical models take from Response Surface Methodology (RSM) is used to make the relation of responses and the other parameters. The desired outputs are minimum radial overcut (ROC) and minimum heat affected zone (HAZ) while the controlling parameters are applied voltage, inter-electrode gap, concentration. These parameter effects the working condition and optimum value.

**Keywords:** Electro-chemical Discharge Machining (ECDM), Genetic Algorithm (GA), Optimization, Pareto optimal, Response Surface Methodology (RSM).

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## 1. INTRODUCTION

Electro-chemical discharge machining (ECDM) is a non-traditional or non-conventional machining process which combines the attributes of both electrochemical Electro-discharge machining (EDM) and machining (ECM) [Mediliyegedara, 2004]. In this process, there is no contact between tool and workpiece line traditional machining. This method can be used to machine nonconductive high strength to weight ratio and hard materials. It can use to the fabrication of the micro hole. The micro-electro-mechanical-system (MEMS) used to development of integrated circuits fabrication processes and other electronic components. By the other conventional and unconventional process, it is difficult to achieve high surface finish and high metal removal rate. A possible mechanism for such machining is Electrochemical discharge machining [Wuthricha, 2005]. To maintain the efficiency of machined products, decrease the machining cost and to improve the machining quality selection of machining tool, it is necessary to select optimal parametre Thus, to meet the desired quality and responses, the process parameters require to be set at their optimum values. This requires first to establish a mathematical model correlating the response and the control parameters. After that, an optimization technique is used to search the optimal control parameter setting for the desired response. Optimization of the ECDM process using GA has been carried out in this research work. Mathematical models to correlate the responses and the control parameters are developed using RSM. The desired results are minimum radial overcut (ROC) and minimum heat affected zone (HAZ) while process

parameter is applied voltage, electrolyte concentration, and the gap between both electrodes.

## 2. LITERATURE REVIEW

Basak and Ghosh, 1997 developed a model and compared numerical results with experimental result to find the metal removal rate. Ghosh, 1997 presented the basic principle and possibilities to improve the MRR of ECDM. Another work done by Bhattacharyya et al., 1999 work on other process parameters to improve the MRR, and find the, materil combination of both the tool to improve the MRR. Kulkarni et al., 2002 were the other researchers to investigate the mechanism of spark generation ECDM process. They paid attention to the relation among the time-varying current, rise of temperature and effect on MRR. A mathematical relation was developed to relate machining parameters with process criteria by Sarkar et al., 2006 they conclude that voltage was more effective parameter to effects the MRR heat affected zone and radial overcut. Chavoshi and Behagh 2014 discussed and investigated the hole length, axial wear parameters and relation among them. That results were shown by Coteate, 2011. Define parametre investigation for the borosilicate glass, and process parameters were optimized using Taguchi's method by Paul and Hiremath, 2013. Adding the surfactant electrolyte concentration, increased the current density and establishment of the current, hence improve the quality Laio, 2013. Hajian et al., 2016 discribe the magnetic field orientation effect on ECDM and find that to increase the magnetic field orientation increase the surface quality and depth. Behroozfar and Razfar, 2016 studied characteristics on the



plasma channel, and material removal rate A. Behroozfar, 2016 and tool wear [Behroozfar, 2015] during ECDM. Dhanvijay and Ahuja, 2014 studied effective machining parameters of stagnant and method to flow of electrolyte on ECDM and results that electrolyte flow method had a high MRR, but a high diametric overcut that had been minimized. A mathematical model was developed by Kamaraj et al., 2015 to predict the overcut of the surface that was important to protect the product dimensions. They also produced micro tools in-house and used them to drill glass.

### 3. EXPERIMENTAL SETUP

This is the experimental setup of ECDM. Which contain too as a cathode and secondary cathode to complete the circuit, gape between both tools is filled with the electrolyte solution. Copper is used as a tool because of high conductivity. To magnification and demagnification of voltage, DC voltage regulator is used. Which can vary the voltage from 30volt to 210volt. For channel cutting, micocontoler is used to move X, Y and Z direction connected by computer.

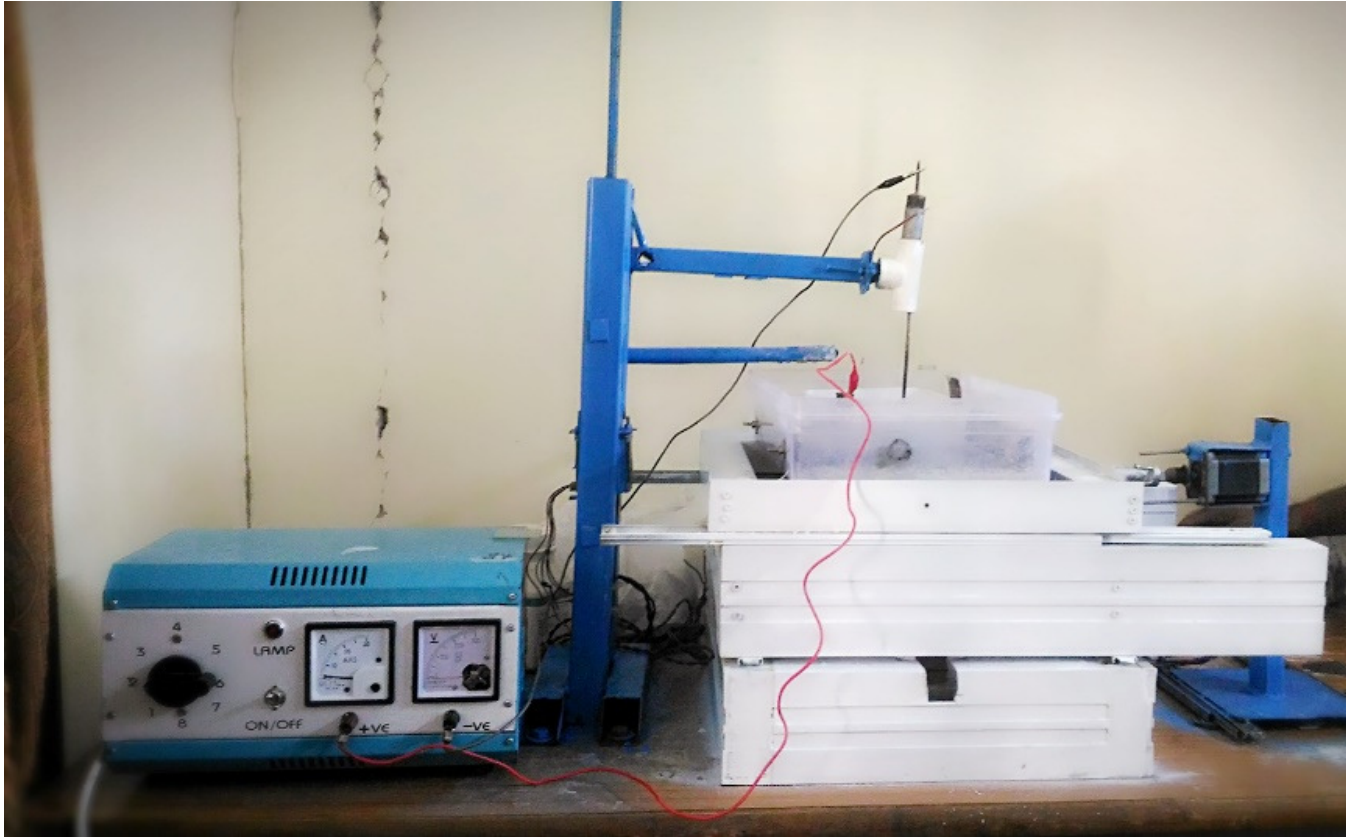


Fig. 1. Schematic diagram of ECSM

### 4. GENETIC ALGORITHMS

Genetic Algorithms (GAs) are optimization technic to use general-purpose search algorithms that use the principles of natural genetics to find solutions of the problems. The basic idea is to maintain a the population of knowledge structure that evolves over the time through a process of competition And controlled variation. Each population structure in the represents a candidate solution to the sfc problem and has an associated fitness to determine which structures are used to form new ones in the process of competition. The new individuals are created using genetic operators, such as crossover and mutation. GAs are best technique great measure optimum value of success in search and optimize.

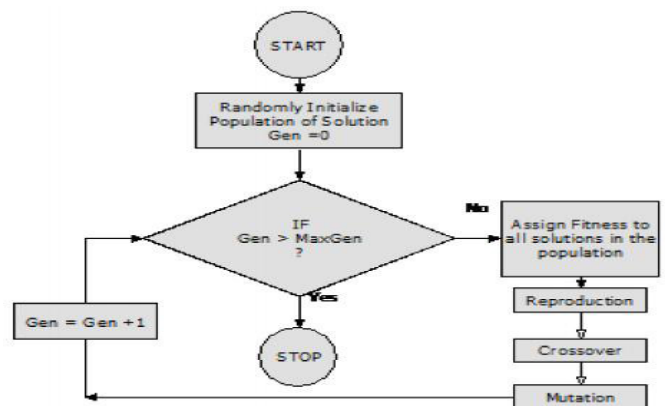


Fig. 2. Flow diagram of GA

## 5. MATHEMATICAL MODELLING AND ANALYSIS

Using RSM process, we find the mathematical relation between all variable parameter such as voltage,

concentration, electrode gap. Table (1) shows the input parameters and level of the parameter. In this paper, all parameters divided into three level.

**TABLE 1: Process parameter and levels**

Level	Voltage(V)	Concentration (gram/liter)	Electrode gap (cm.)
1	150	30	14
2	180	35	16
3	210	40	18

For the calculation of material removal rate in all workpiece by

$$\text{MRR} = \frac{[\text{Initial Weight of work piece} - \text{final weight of workpiece} - \text{final weight of workpiece}]}{\text{Time}}$$

**TABLE 2: All set of experiments and MRR**

S.N	VOLTAGE (V)	CONCENTRATION (gm/l)	INTER ELECTRODE GAP(cm)	MRR (gm/min)
1	180	40	14	0.011110
2	180	30	18	0.008330
3	150	40	16	0.006520
4	210	35	14	0.021110
5	180	35	16	0.016250
6	210	35	18	0.017850
7	180	35	16	0.020100
8	150	35	14	0.015120
9	210	30	16	0.018181
10	150	30	16	0.005120
11	180	35	16	0.017120
12	210	40	16	0.020830
13	180	30	14	0.008900
14	180	40	18	0.010770
15	150	35	18	0.007650

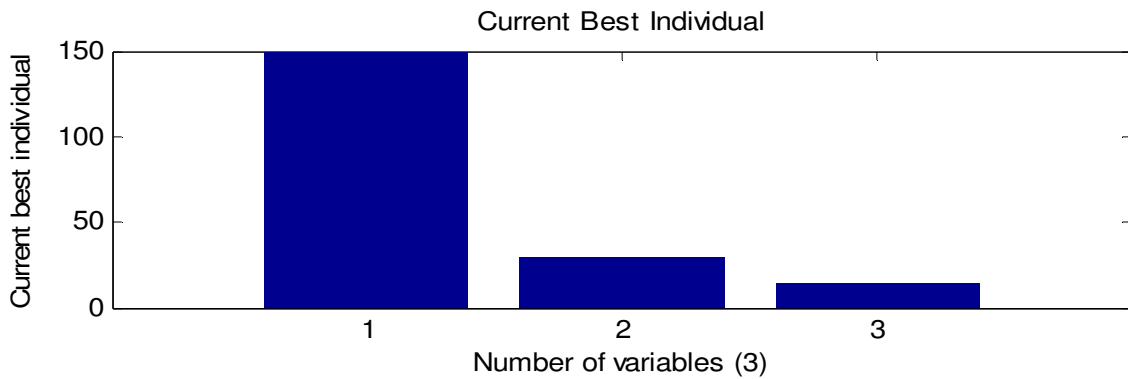
Table(2) shows that set of experiments which was taken from RSM and the actual output of the machine in the form of metal removal rate. A mathematical relation developed between voltage, concentration and electrode gap to the calculation of MRR.

Regression equation for material removal Rate  
 $\text{MRR} = -0.320 + 0.001024 \text{ voltage} + 0.00555 \text{ concentration} + 0.01506 \text{ electrode gap} - 0.000002 \text{ voltage} * \text{voltage} - 0.000055 \text{ concentration} * \text{concentration} - 0.000329 \text{ electrode gap} * \text{electrode gap} + 0.000001$

$\text{voltage} * \text{concentration} - 0.000010 \text{ voltage} * \text{electrode gap} - 0.000083 \text{ concentration} * \text{electrode gap}$

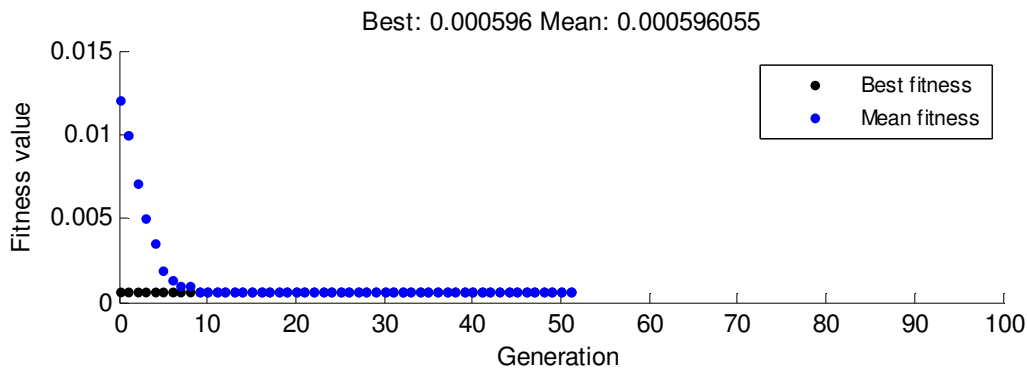
## 6. ANALYSIS OF OPTIMIZED RESULTS

GA optimization technique finds the contribution in MRR with various parameters. It represents that in all parameters, voltage is the most effective parameter to change the material removal rate. It means the contribution of voltage is highest to determine the MRR after voltage, concentration and further electrode gap.



**Fig 3. Most significant factor in GA Optimization**

Below figure demonstrate the relationship between fitness function and the number of generation. In this fitness function GA takes 50 generation. The number of generation value is increased fitness value also decreases at a certain limit. After this limit it goes to constant.



**TABLE 3: Observation table**

	Input parameters	Response
GA optimized result	Voltage 150 Concentration 30 Inter electrode Gap 14	$MRR_{opt} = 5.95 \times 10^{-4}$
		$MRR_{max} = 0.08196$
Experimental MRR		$MRR_{exp} = 0.0786$
% error		4.09 %

Table (3) imply the comparative analysis between experimental results and optimized results. A vacation experiment was dined at suggested parameter by GA tool, and 4.09 % error is found.

## 7. CONCLUSION

To optimize the ECSM process variable genetic algorithm is successfully used, that provide a best optimize results for considered process output. Percentage error noticed for Material removal rate is 9% that is acceptable for the model. Therefore it can say that genetic algorithm approach

is suitable for experimental analysis to achieve optimized output. In the optimization of all variabal GA shows thar voltage contibution is higest. And after VOLtahe concentration is more effective parametre which effects the metal removal rate.

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# Experimental Investigation to Optimize Process Parameters of Non Conducting Material with Hybrid Non Conventional Machining

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**Abstract:** Among all non-conventional, electrochemical discharge machining (ECSM) we have a high quality of material removal rate without any stress generation on workpiece. This machine has been accepted as a highly modern material as the workpiece for other micromachining. In this paper an effort has been done on micro drilling of borosilicate glass using non-conventional hybrid machine. A copper tool and a transformer have been used to support the steady machining to increase the accuracy of micro hole. The input parameters used in this experiment are voltage, concentration, inter-electrode gap, area of both electrode is constant during the whole process. Optimize MRR has been investigated over the given parameters. Flow of electrolyte and electrolyte temperature has been constant. In this paper, we use the Taguchi method to optimize the MRR (metal removal rate) by effect of the process parameters.

**Keywords:** Electrochemical Discharge Machining (ECSM), Taguchi Technique, Material Removal Rate (MRR), Signal to Noise (S/N) ratio.

## 1. INTRODUCTION

The ECSM have lots of applications for machining of non-conducting engineering materials such as glass and ceramics. In the non-conventional field for all conductive material electrochemical machining (ECM) and electrical discharge machining (EDM) are two powerful tools available. However Glass and composite materials are two great examples of nonconductive material, but high application in industry and general life. The technical requirements for glass and other non-conductive material in micro application are growing day by day. Medical science needed biocompatible materials is only one of many examples. The Use of glass is also increased in the area of Micro Electro Mechanical Systems (MEMS). Glass has some very useful property such as chemical resistance and biocompatibility. Because the glass is transparent, it is often used in optical applications. To respond this need and industrial requirement of machining of glass and similar brittle non-conducting materials, The studies seek to improve the quality and characteristics of ECSM. To optimize the result, a parametric study based on the Taguchi method was performed to optimize the process parameter as MRR (material removal rate) for ECSM process by controlling important parameters, such as voltage, electrolyte concentration and inter electrode gap

## 2. EXPERIMENTAL SETUP

Electrochemical spark machining (ECSM) is combination of two technique electrochemical machining (ECM) and electric discharge machine (EDM) used to process

conductive and non-conductive materials, ie, silicon, glass, ceramics, composites, etc. In ECSM when voltage was applied above the critical point the spark produced between the electrolyte and electrode and that spark is known as electrochemical spark and that electrolytic spark was used for material erosion in ECSM. So in this machining setup the material removal rate or machining rate can be controlled by varying the intensity of spark.

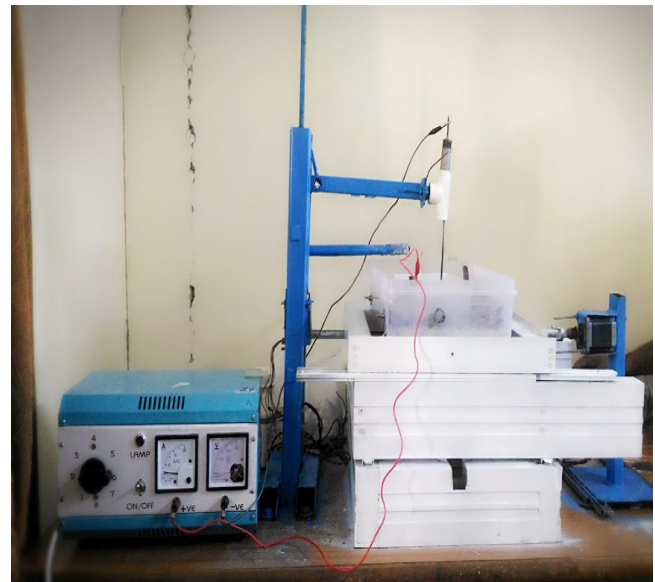


Fig. 1. ECSM experimental setup

### 3. EXPERIMENTAL DATA ANALYSIS

In this study the L9 orthogonal array was used for the various machining parameters. There were three parameters which varies in three levels as shown in Table I. In Taguchi method the experimental values are converted into the S/N (signal to noise) ratio. The experimental values analysis in S/N ratio based on “smaller the better” and “large the better”. The process parameter level having maximum S/N ratio is considered as a optimal. To maximize the material removal rate is the objective of this study. Electrolytic concentration, voltage, inter electrode gap are the three parameters which affect the MRR. The glass of borosilicate is used as work piece which is non conductive material.

**TABLE 1: Design scheme of experiment of parameters and levels**

S.No	Process Parameter	Level		
		150	180	210
1	Voltage			
2	Electrolyte Concentration	30	35	40
3	IEG	14	16	18

In Table II. The result and S/N ratio for MRR are shown, it optimized the combination of process parameters like V, EC and IEG. The maximum value of S/N ratio is calculated for optimized combination of parameters as higher MRR.

**TABLE 2: S/N ratio for MRR (Larger is better) and experimental results**

S.No.	VOLTAGE(v)	CONCENTRATION (g/lit.)	IEG(cm)	MRR(gm/min)	S/N Ratio
1	150	30	14	0.005120	-44.8579
2	150	35	16	0.007900	-43.2446
3	150	40	18	0.007650	-42.0863
4	180	30	16	0.012010	-38.1687
5	180	35	18	0.011110	-38.1290
6	180	40	14	0.020100	-35.1332
7	210	30	18	0.081810	-36.0048
8	210	35	14	0.019125	-34.1275
9	210	40	16	0.024120	-31.3957

- Material removal rate per unit time is calculated as:

$$MRR = \frac{\text{Area X Thickness}}{\text{Time of machining}}$$

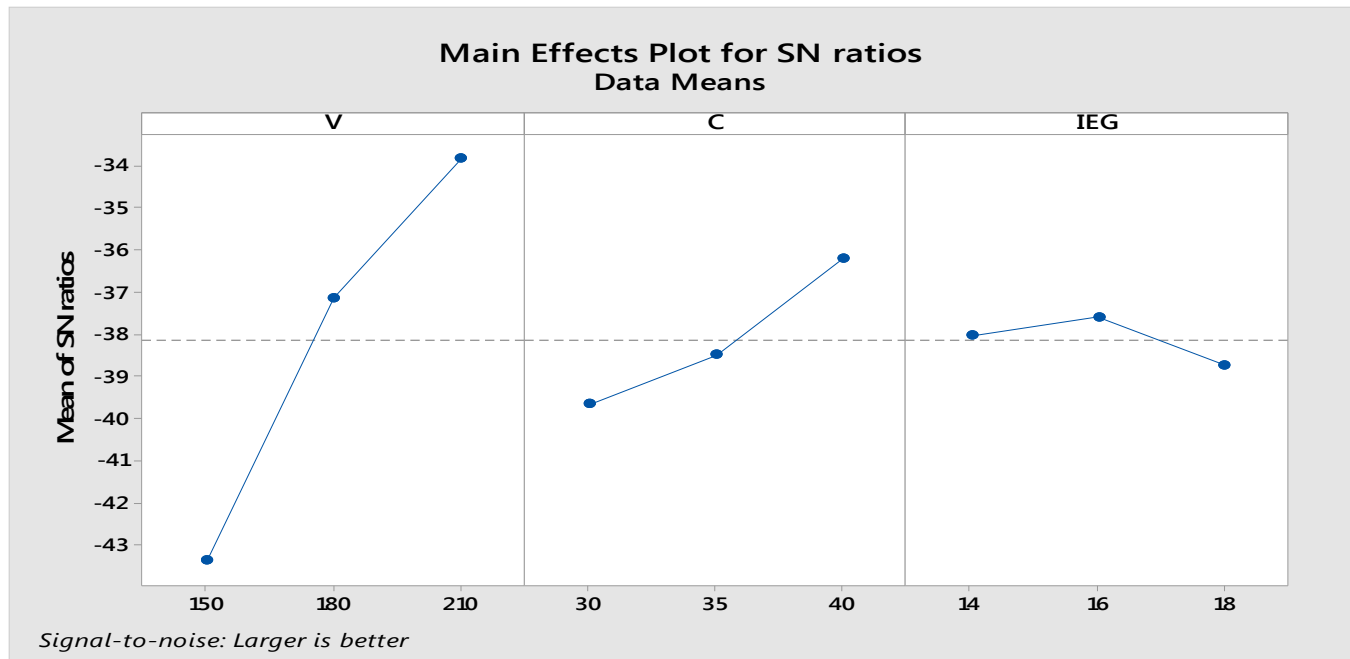
- Signal to Noise ratio (S/N) of larger is better is calculated as:

$$\eta_{ij} = -10 \log \left( \frac{1}{n} \sum_{j=1}^n \frac{1}{y_{ij}^2} \right)$$

### 4. RESULTS AND DISCUSSION

Electrolytic concentration, IEG and voltage are used as a input variable to obtain the response in MRR. Taguchi analysis is done for the parameters mathematical modelling. This discussion concentrates on the different parameters of the process to the observed values MRR based on the Taguchi methodology.





**Fig. 2. Larger is better S/N graph for MRR**

The effect of MRR of each parameter at different level is shown in Fig. 2. According to Fig 2. MRR increases with the increase in the level of voltage due to increase in the intensity of spark. That high spark intensity increases the MRR. In case of electrolyte concentration (C), MRR increases with increasing rate of electrolytic concentration. Due to formation of bubbles that is responsible for spark formation.

And in the case of inter electrode gap (IEG) according to fig.1. it is observed at first the MRR increases with gap after obtaining a certain gap its graph goes down because the gap between electrodes increases that decreases the current density and spark frequency.

## 5. CONCLUSION

This paper presents the study on the taguchi of L9 orthogonal array method for investigating the effects of various parameters on MRR in ECSM. From this paper study it is concluded that at higher voltage, higher electrolytic concentration and at a certain inter electrode gap we obtained the higher MRR. Input parameters inter electrode gap, electrolyte concentration and voltage are termed as a signal and the MRR (response) is termed as a noise. It is concluded that:

- 1) The analysis of the experimental values for higher MRR has shown that taguchi parameter design can successfully verify the optimum machining parameters, which are voltage = 210 V, inter electrode gap (IEG)= 16 cm and electrolyte concentration (EC)= 40 g/lit.

- 2) Voltage effect on MRR is almost linear.
- 3) MRR increasing with increasing electrolyte concentration and voltage and MRR increases first to certain value then decrease with increase in inter electrode gap.

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# Application of Artificial Neural Network (ANN) for Analysis of Abrasive Jet Machining

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**Abstract:** Artificial neural networks (ANN) have been introduced a well-organized and effective approach to predict the resulting Material removal rate (MRR) and Sphericity constant ( $S_C$ ) of abrasive jet machining (AJM) process. ANN prediction technique can utilize to improve the AJM process approach and thus help in process planning and optimum selection of controlling parameters. This paper discusses the development of neural network pattern using MATLAB for process parameters. Here Taguchi L16 orthogonal design conducted for model variables. MRR and  $S_C$  are considered as responses. 4-10-2-2 network configuration is suggested for ANN model. Levenberg-Marquardt backpropagation algorithm (LMBPA) is utilized for Training, testing, and validation of feed-forward neural network. The correlation coefficient (R) is above 95% for developed ANN model that implies the best fit with experimental outcomes. Prediction error was found using mean absolute percentage error (MAPE) methods.

**Keywords:** ANN, MRR,  $S_C$ , MATLAB, MAPE, LMBPA

## 1. INTRODUCTION

Abrasive jet machining (AJM) process is non-traditional machining technique in the field of micromachining. Presently, complex three-dimensional (3D) cutting by employing newer machining methods is the more curious field of research. Eventually, this operation is widely utilized as a part of the industry for cutting intricate shape on hard and brittle materials that usually difficult to perform.

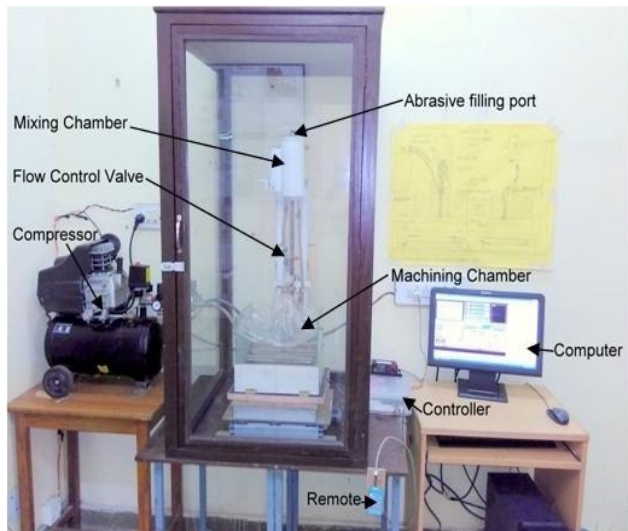


Fig. 1. AJM setup at Govt. Engg. College, Ajmer

In this Method, abrasive particles are accelerated by compressed air through a nozzle and strike with the workpiece. Material removal occurs by the collision of

abrasive powders with the workpiece. The Kinetic energy of the abrasive particle is responsible for removing the material. Today it has grown into a full-scale production process for nonconductive materials such as glass, silicon, and quartz which have a high fracture tendency.



Fig. 2. Jet impingement through nozzle

## 2. DATA COLLECTION AND EXPERIMENTATION

The Experiments were conducted on the AJM setup shown in fig1 by considering Pressure, nozzle inclination (NI), stand-off distance (SOD) and nozzle diameter (ND) as machining variables. MRR and  $S_C$  are performance measure on glass workpiece. Material removal and sphericity of

crater is measured by digital weighing machine and USB digital microscope respectively. Taguchi L16 experiments

are conducted on abrasive jet machining dataset are demonstrated in table I.

**TABLE 1: Selection of controlling factors**

Control factor	Levels				Response	
	1234					
Pressure (Kgf/cm ² )	3	4	5	6	Material removal rate (MRR) (gm/sec.)	Sphericity constant ( S _C )
Nozzle inclination (deg.)	54	66	78	90		
SOD	5	10	15	20		
Nozzle diameter (mm)	1.5	1.7	1.9	2.1		



**Fig. 3. Sphericity and weight measurement of machined hole**

### 3. ARTIFICIAL NEURAL NETWORKS (ANN)

In a neural network, the word network alludes to the interconnection between all neurons exhibit in different layers of a framework. Each neural system is fundamentally having a three-layer system which are Input layer, Hidden Layer, and an Output Layer. Input layer also called information layer that having input neurons which assign an information data using synapses to the intermediate hidden layer and likewise this data transfer to the output layer using more neural connections.

#### 3.1 Back Propagation Training Algorithm

Backpropagation is a way of training the artificial multilayer neural network through the use of the supervised learning rule. Basically, a supervised algorithm is error correction learning algorithms which use an external reference signal and develop an error signal by correlating the reference with the computed output.

On the base of errors of the signal, synaptic weights of neural connections are modified to enhance the network performance. BPA is an iterative gradient descent algorithm planned to minimization of the sum of squared errors. Here

can be as many synaptic weight vector of existing neuron in present model ( $\omega_{ki}$ ) is multiplied with the input signal to thenetwork ( $x_j$ ) then this product added in biased value ( $b_k$ ) that develop a gain or summation function ( $u_k$ ) that goes to an activation function  $f(v)$ . For this model, the output of a typical interval activity (linear combiner) of a neuron  $k$  can be computed as

$$U_k = \sum_{i=1}^n \omega_{ki} X_i \quad (i)$$

The total aggregate input to unit  $k$

$$V_k = u_k + b_k \quad (ii)$$

Typically neurons could be associated with several neurons, or it may be receiving information input from various source using synaptic weight vector  $\omega_n$ . A neuron structure model also comprises an applied bias input ( $b_k$ ) which has the effect of increasing or decreasing the net input of the activation function, based on whether the bias value is positive or negative. For limiting the amplitude of the neuron output squashing function (Activation function)  $y$  shown in Eq. (iii).

Mathematically signal output for  $k^{\text{th}}$  neuron

$$Y(k) = f\left(\sum_{i=1}^N \omega_{ki} \cdot X_i + b_k\right)$$

$$Y = f$$

$\omega_{ki}$  -weight associated with  $i^{\text{th}}$  input

(iii)

The activation function determined the signal output of neural in term of summing function (v). Most generally used activation functions are sigmoidal function and Threshold function.

(v)

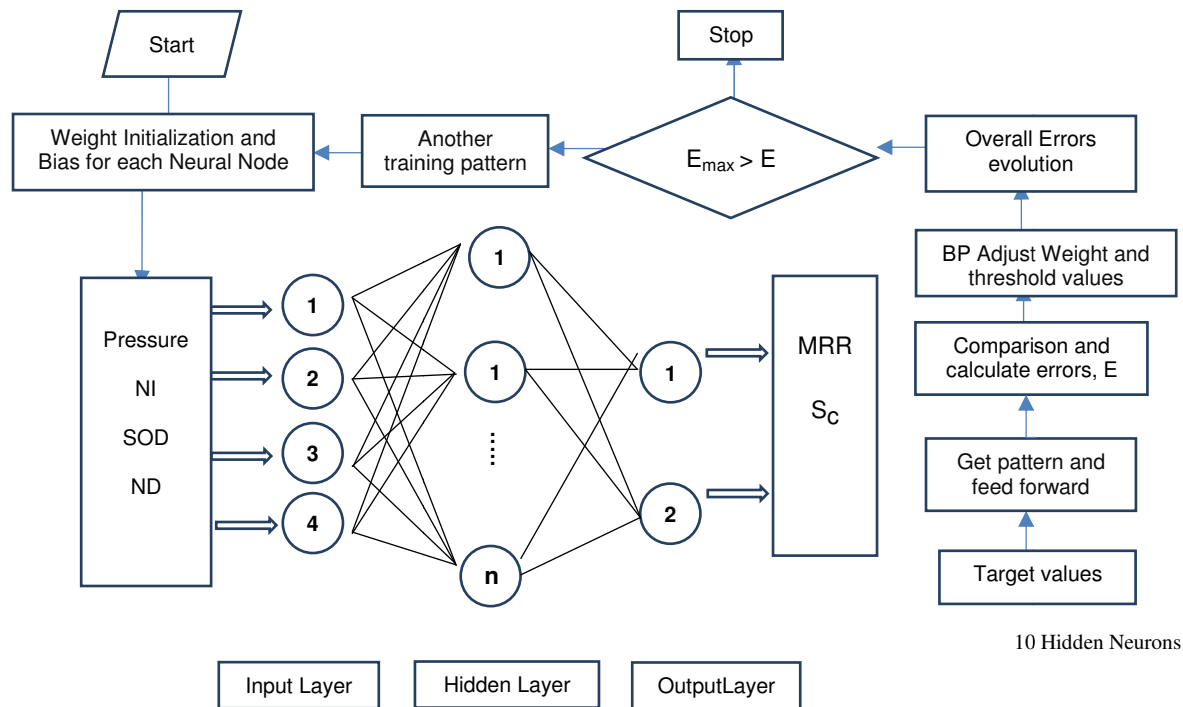


Fig. 4. Flowchart of ANN modeling

#### 4. ANN PREDICTION MODELING FOR AJM PROCESS

For developing an ANN model information data are acquired by Taguchi L16 experiments for abrasive jet machining process model. Again, pressure, NI, SOD and ND are determined as effective control variables on the MRR,  $S_c$  respectively as shown in Table II. A various number of architecture are tested for these collected data with feedforward backpropagation network by employing nftool in MATLAB R2013a.

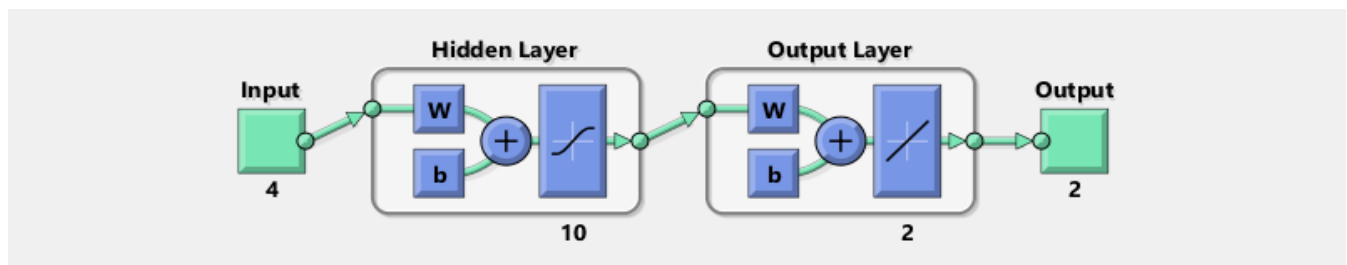


Fig. 5. 4-10-2-2 pattern for ANN model

A neural network has been developed to find a pattern that can predict MRR and  $S_c$  relevant to Abrasive jet machining using glass workpiece. The final BPN is a 4-10-2-2 with 10 hidden neural nodes, 4 input nodes, and 2 output nodes have been framed. Hence, Feedforward neural network with backpropagation algorithm and Levenberg-Marquardt algorithm were trained for the analysis of the gathered experimental data. Complete the efficiency of the ANN model totally depending on trial and error strategy. The modeling used by ANN consists of the following characteristics that listed in Table II.

**TABLE 2: ANN model configuration**

Type of neural network	Feedforwardbackprop
No. of neurons in hidden layers	10
Input neurons (nodes) for neural model	Pressure, Nozzle inclination, standoff distance, Nozzle diameter
Output neurons	Material removal rate and sphericity constant
ANN model architecture	4-10-2-2
Learning method used	Levenberg- Marquardt backpropagation algorithm (LMBP)
Training function	TRAINLM
Adoption learning function	LEARNGDM
Performance function	MSE
Transfer function	TANSIG (sigmoid function)

The predicted demonstrates that the neural model can anticipate both responses with high precision by implementing LMBP algorithm. The pattern of the neural network is preparing to use 60% of input data to learning, 20% for validation and remaining 20% utilized for testing of pattern performance.

## 5. RESULTS AND DISCUSSION

Above Table shows the experimental set at different levels

of machining variable that further provide to ANN model for data learning.

Figure 6 represents the regression graph for both responses. The correlation coefficient (R) for all data is observed to be 0.99334, almost equivalent to 1, which shows the good correlation. All the data obtained from best fit .above correlation curve also defined the performance of training, testing and validation of data set.

**TABLE 3: Experimental Design Matrix with Predicted data**

S.No.	Process Variables				Experimental values		Predicted values	
	Pressure (kgf/cm ² )	NI (degree)	SOD (mm)	ND (mm)	MRR (gm/sec)	S _c	MRR (gm/sec)	S _c
1	3	54	5	1.5	0.0075	0.725	0.0076414	0.7249984
2	3	66	10	1.7	0.02083	0.827	0.020824	0.82698
3	3	78	15	1.9	0.04253	0.901	0.042524	0.900979
4	3	90	20	2.1	0.046259	1	0.062066	0.938584
5	4	54	10	1.9	0.02833	0.697	0.027639	0.577405
6	4	66	5	2.1	0.017018	0.789	0.02051	0.72873
7	4	78	20	1.5	0.0246	0.849	0.024606	0.848994
8	4	90	15	1.7	0.04517	1	0.045167	0.999997
9	5	54	15	2.1	0.04328	0.645	0.043284	0.644978
10	5	66	20	1.9	0.047808	0.804	0.042129	0.738543
11	5	78	5	1.7	0.01975	0.84	0.019719	0.840041
12	5	90	10	1.5	0.031718	1	0.031722	0.999989
13	6	54	20	1.7	0.0366	0.669	0.044626	0.857078
14	6	66	15	1.5	0.03514	0.774	0.035155	0.774077
15	6	78	10	2.1	0.042056	0.828	0.037954	0.922286
16	6	90	5	1.9	0.05048	1	0.050464	0.989960

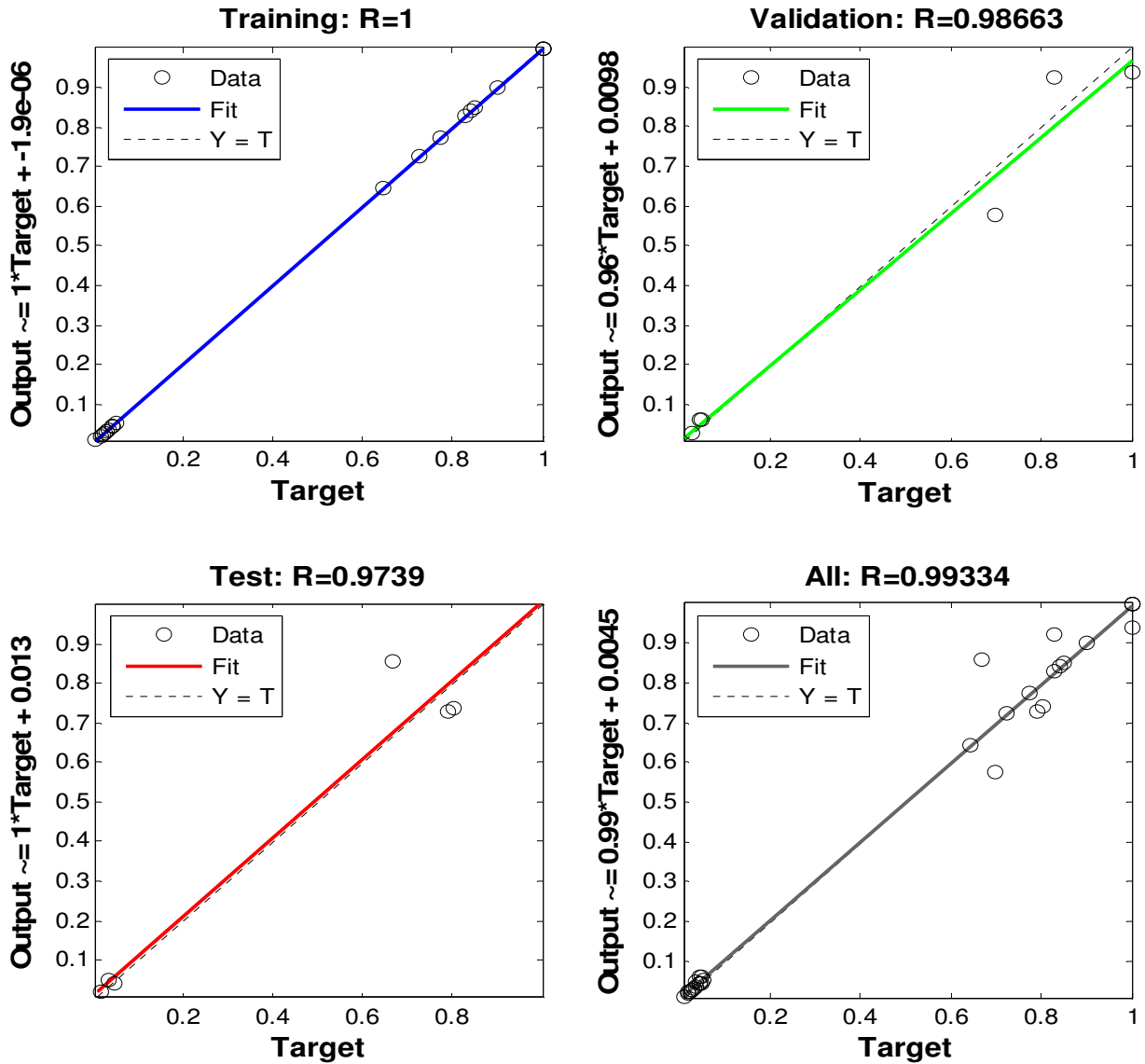


Fig. 6. Regression plot

By statically perspective, R should be acquired equal or greater to 95%. In present process modeling the outcome obtained were at 0.973 for thetest, 0.986 for validation and 1 for thetraining of experimental dataset which results with very low mean square error (MSE).

TABLE 4: Basic Characteristic Values for Response

	Outputs
Best validation performance	Epoch 5
R value	Training 0.96061, validation 1 testing 1 All 0.8887
Performance (mse)	$1.27 \times 10^{-16}$
gradient (plottrainstate)	$1.89 \times 10^{-9}$ at epoch 6
Mu (plottrainstate)	$1 \times 10^{-9}$ at epoch 6

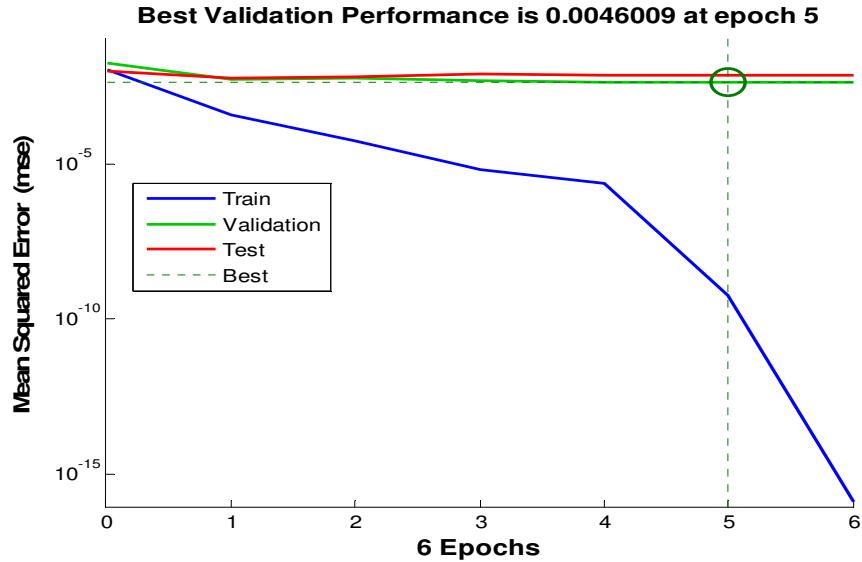


Fig. 7. Neural network training performance

The MSE is a difference between model predicted value and a target (experimental value). The least MSE (close to zero) means that ANN output and desired output in training data set has become very near to each other. Variation in mean square error of training, testing and validation data set at concerning epoch has been shown in Fig. 7. It also shows the developed pattern performance. Here best, model performance is obtained at epoch 5 is 0.0046009. As it can be found in the performance plot, the mean square error

(MSE) of the ANN has diminished with the number of epochs. The ANN model was well trained hence showed a low MSE towards the end of the training stage. MSE is calculated using equation 4.1

$$MSE = \frac{1}{n} \sum_{k=1}^n (e)^2 = \frac{1}{n} \sum_{k=1}^n [t(k) - y(k)]^2 \quad (iv)$$

nn

Where  $e$  = error between target  $t(k)$  and ANN predicted  $y(k)$  values

## 6. COMPARATIVE OBSERVATION

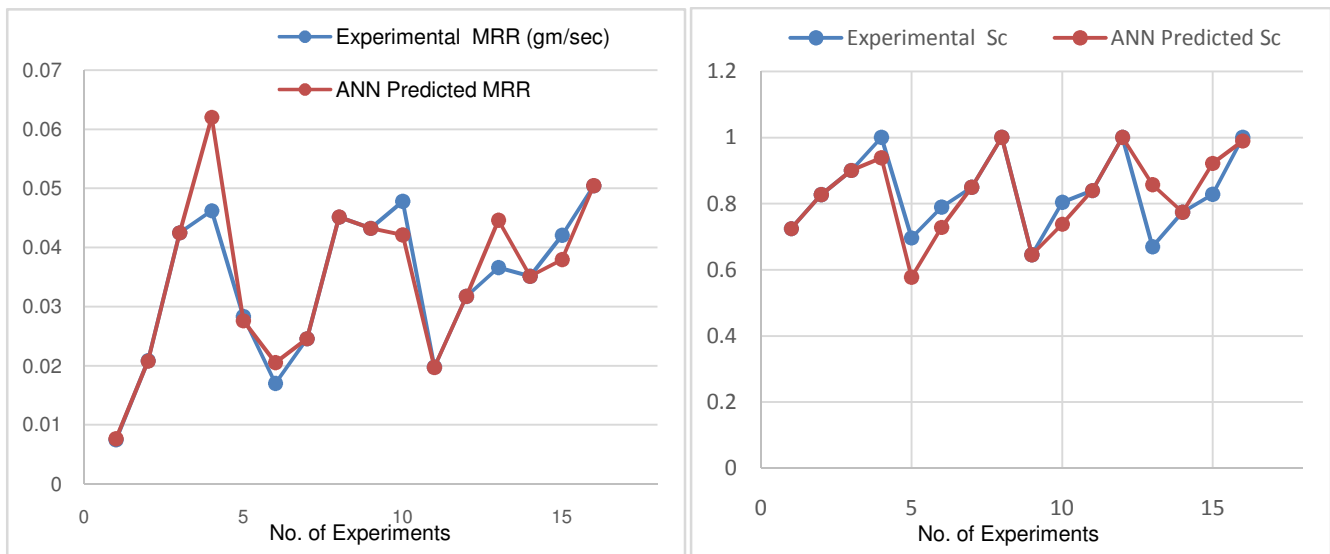


Fig. 8. Comparison of predictive vs Experimental values for MRR and  $S_c$

$$\text{MAPE \%} = \frac{\text{ANN Predicted value} - \text{experimental value}}{\text{ANN Predicted value}}$$

(v)

For each input of neural pattern, the ANN predicted the value of MRR and  $S_c$  is compared with the respective experimental value and the mean absolute percentage error (MAPE) is determined as equation (v).

## 7. CONCLUSION

The results delineate that the data values from training and predicted values have achieved near each other. Regression plot of ANN model to train, test and validation of data exhibits the best-fitted data for network targets which fall along 45-degree line. Assessment of experimental and forecasted values of MRR and  $S_c$  by implementing ANN model are classified in Table ii that signify the best performance of ANN pattern for process characteristics. LMBP used to build the neural network with 70% of training data gives good forecasted results. MAPE for both responses found 5.58%, 4.84% respectively that is satisfactory.

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# Abrasive Water Jet Machining of Composites: A Review

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**Abstract:** This paper describes a literature review in the domain of abrasive water jet machining (AWJM) of composites. Worldwide researchers have applied efforts to study the influence of various process parameters of AWJM including water pressure, stand-off-distance, traverse speed, abrasive mass flow rate on responses such as surface roughness and kerf taper. Efforts are also applied to find the optimum combination of process parameters for minimum kerf taper and surface roughness of machined samples. In the present paper, some published papers are reviewed and finally based on the literature review; future scope of research work in AWJM of composite is also identified.

## 1. INTRODUCTION

Abrasive water jet machining (AWJM) is used in many industrial applications such as drilling, milling and processes including no tool wear, high material removal rate, negligible heat affected zone and good surface finish. In AWJM material removal depends on the erosion caused

by impact of jet. It uses constant abrasive slurry created by the mixing of abrasive particles in to a high pressure water jet. This high pressure water jet transfers kinetic energy to abrasives to accelerate them. Through erosion and summation of cutting action by a large amount of abrasives remove material at high rate.

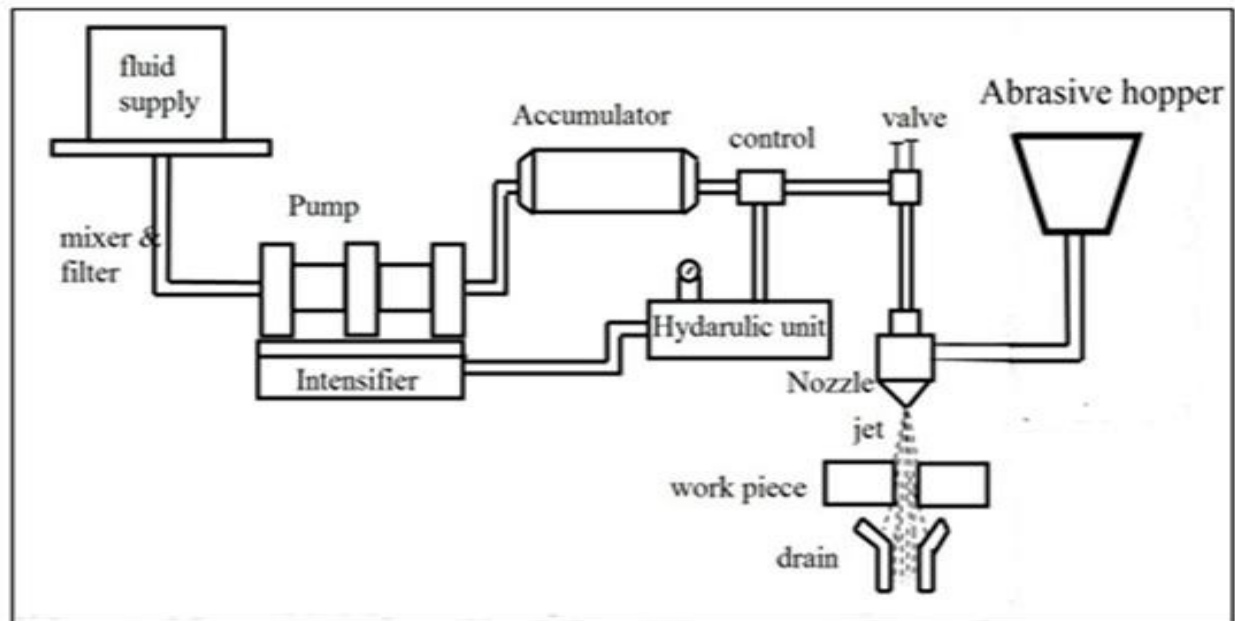


Fig. 1. AWJM set-up (Khan and Ali, 2011)

Composites would be the materials consisting of several chemically different constituents on a macro scale having a different interface separating them whose mechanical properties are superior to those of individual components acting independently. Composites routinely have a fibre or partial phase that's stiffer and stronger than the continuous matrix phase. Many types of reinforcement also often have good thermal and electric conductivity, a coefficient of

thermal expansion that's less compared to the matrix and good wear resistance. Composites are widely utilized in aerospace, transportation, marine and sports equipments. Application of composites in these sectors demands precision defect free machining. But the traditional machining processes aren't ideal for machining of composites, as a result of excessive tool wear, high temperature affected zone, fibre take out and delamination.



AWJM is one of the most suitable non-traditional machining process for composites. Worldwide researchers have applied efforts to study AWJM of composites to ensure defect free machining. The present paper reviews the work done by various researchers in this domain.

As far as AWJM of composites is concerned the size of abrasive, hydraulic pressure and traverse rate are the more significant process parameters as compared to other process parameters such as standoff distance and abrasive flow rate. But in cutting of composites especially laminate composites, delamination is the main composite defect. While AWJM of composites, abrasive water jet creates shocks wave impact on material because of which cracks tips are generated in the work piece material at initial cutting stage. Now the pressurized AWJ be net rates in to the cracks tips which tend to water wending and abrasive embedment. (Shanmham et al, 2008)

## 2. LITERATURE REVIEW

Many researchers have applied their efforts in the domain of AWJM of varied forms of composites. Arora and Ramulu (1996) studied the kerf characteristics of abrasive water jet (AWJ) machined graphite epoxy composite. It is available that entry kerf width is more affected by standoff distance as compared to exit kerf width.

Wang (1999) investigated machinability of polymer matrix composites under AWJM. The mathematical models are developed to find out the influence of process parameters namely transverse speed, water pressure and standoff distance on kerf geometry.

Lemma et al. (2002) studied oscillation cutting and normal AWJ cutting of glass fibre reinforced polymer composite. They concluded that there's an important reduction in surface roughness produced by oscillation than normal cutting. The improvements in surface roughness are better each time a large value of oscillation angle and oscillation frequency is utilized.

Azmir and Ahsan (2008) investigated the top of glass wm-215TA epoxy composite machined by AWJM. It absolutely was identified that the grade of cut may be improved by increasing abrasive hardness and water pressure. Fibre orientation has very less effect on the grade of cut. Further, they (Azmir and Ahsan, 2009) studied the influence of hydraulic pressure, kind of abrasive material, stand-off distance (SOD) and traverse rate on the surface roughness and kerf taper of GFRP laminate machined by AWJM. It is available that the roughness and kerf taper decrease with escalation in water pressure and hardness of abrasives.

Shamugamet al. (2008) examined the delaminating process I graphite epoxy composites in AWJM. They have concluded the shock wave impact of water jet cutting stage

and water welding and abrasive embedment advances the delamination.

Ramulu et al. (2009) studied the quantity of machined surface of polymer and metal fibers composite damage characteristics were investigated terms of delamination and hole defects. An organized experimental work was perform to examine the influence of process parameters contributing to surface quality and damage induced in cutting and drilling of CFRP and hybrid composites. The comparison study discover AWJM is preferable to WJM considering surface roughness and delamination.

(Azmir et al 2009) Examined the aftereffect of AWJM parameter on kerf taper ratio and roughness aramid fiber reinforced plastic composite. They figured kerf taper and surface roughness decreases with increasing water pressure and with decreasing SOD and traverse rate.

(Cosansa et al 2012) studied the cutting process outcomes of AWJM such as for instance surface roughness, surface waviness and kerf-taper angle using colemanite power as abrasive in AWJM with variable abrasive flow rate and traverse rate. It absolutely was figured kerf tape angle, surface roughness and surface waviness increases with increases with increases in traverse rate. Cutting tool confirms that the co-laminate powder is an alternative of abrasive water jet process in the event of garnet and other high hardness powder shortage occurs.

(Alberi et al 2013) studied the procedure parameters of AWJM on CFRP and GFRP and discover the machinability index and redefine the separation speed. It absolutely was observed that traverse speed relative to separation speed depends on the thickness may be cut using certain cutting conditions without observing any delamination.

(Srinuash and Axinte 2014) discover surface integrity of plain water jet milled advanced engineering composites materials. It absolutely was observed that by suitably controlling the energy of jet and by the mix of adjustable process parameters; harm to the fibre may be eliminated.

(karakur et al 2014) discover the impact of process parameter of AWJM on granite and abrasive the kerf width .It was figured small SOD and high traverse rates are prescribed to get narrow kerf widths. Water absorption, the unit weight, the micro hardness and the main grain size of the granite have important connections with the kerf widths of the tested granite.

(Dhanawade et al 2016) discover the aftereffect of Abrasive flow rate, traverse rate, abrasive mass flow rate, and SOD and water pressure of AWJM on carbon epoxy composite. Process optimization is performed by Taguchi methods and analysis by the ANOVA. It absolutely was figured kerf tapper and surface roughness decreases with escalation in pressure and with decreasing traverse rate.

(Kumar et al 2016) Investigated on wear behaviour of material such as for instance asbestos, Kevlar, glass fibre, graphite and natural fibre composites under various speed and contact load. The three distinct brake pad materials were analyzed to displace above composites are flax fibre reinforced phenol composites (FFRC), blast (BFRC) and hybrid (HFRC). The outcomes showed BFRC is preferable to one other composites examined due to good bonding nature of blast fibre and thermal characteristics advances the wear resistance of BFRC extensively.

(Yahiya et al 2016) examined the influence of kerf fiber orientation on the mechanical properties of kerf aramid hybrid composites for military vehicle spall liner application. It absolutely was seen that the charpy impact strength and tensile strength of woven kerf hybrid composite are higher than that of unidirectional and mat. Mat kerf hybrid composites has low density, high water absorption rate, high swelling of fibers and less dimensional stability as you can find high void contents. Hybrid composites with woven and unidirectional kerf are nearly same in density and void content.

### 3. RESEARCH GAP IDENTIFICATION

Researchers	Investigation on	Material	Future Scope
Arora and Ramula (1996)	Kerf geometry with depth of cut	Graphite and epoxy composite	Surface roughness and be measured
Wang (1999)	Kerf geometry	Teflon Phenolic composites	Surface roughness and delamination can be measured
Lemma (2002)	Surface roughness with head oscillation	Glass fiber reinforced polymer composites	Kerf fiber ratio can be measured
Azmir and Ahsan (2008)	Surface roughness with head oscillation	Glass fiber reinforced polymer composites	Thickness of material can be measured
Shanumugam (2008)	Delamination	Graphite (GY 70 – carbon fiber) and epoxy (934) resin composites	Kerf taper and surface roughness can be measured
Hazmir and Ahsan (2009)	Kerf taper and surface roughness	Glass/ epoxy resin	Depth of cut can be measured
Ramulu et al (2009)	Surface roughness and delamination	Carbon fiber rain force polymer composite	Kerf taper can be measured
Azmir et al (2009)	Kerf taper ratio and surface roughness	Aramid epoxy composite	Delaminations can be analyzed
Cosansa et al (2012)	Surface roughness, Surface waviness and kerf taper angle	A17075, marble glass, Ti6Al4V and composite material and co-laminate powder as abrasive.	Cutting of co-laminate powder can be improved by using different particle geo and different size of powders.
Aberdi et al (2013)	The machinability index and redefine the separation speed	CFRP and GFRP	Depth of cut can be evaluated
Sriniousu and Axinate (2014)	Fiber damage analyses	Carbon fiber, glass fiber and carbon/glass fiber composites	Surface roughness and kerf taper can be evaluated
karakur et al (2014)	Kerf taper ratio	Granite	Surface roughness can be evaluated
Dhanawade et al (2016)	Surface roughness and kerf geometry	Carbon epoxy composites	Machining with cutting head oscillation can be done
Kumar et al (2016)	Wear behavior	Basalt fiber reinforced phenolic composites, flux/basalt reinforced hyper phenolic composites and flux fiber reinforced phenolic composites	Development of composites which can replace assesbetos from brake pads
Yaha et al (2016)	Mechanical properties	Kenaf- aramid hybrid composites	Advances in ballistic protection gears with use of hybrid composites

#### 4. COMMENT ON LITERATURE

Researchers have invented, optimized and developed models for the cutting performance measures including kerf taper, surface roughness, material removal rate and depth of cut in AWJM of glass epoxy composites etc. Researchers have studied the aftereffect of water pressure, abrasive mass flow rate, standoff distance, traverse speed etc. on depth of cut, surface roughness, kerf taper, material removal rate etc. Very less work has been on AWJM of Kevlar epoxy composites.

#### 5. CONCLUSION

Offered literature in the area of AWJM of composite is reviewed and reviewed in this paper. The published research work is divided in two main domains namely investigation on cutting performance, with various materials of AWJM process. The major research work has been made clear in tabular form and scope of further work has recently been determined. It has been found more research is required in this domain to improve dimensional accuracy of machined composite part. Even more there is demanding need to apply efforts to optimize process parameters for multi performance characteristics. Predictive types of delamination, kerf geometry, depth of slice, etc. for various composite are also required to be developed. Further, very less work is reported in literature on AWJM of epoxy resin and Kevlar material.

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# Laser Beam Machining Parameters Analysis and Optimization

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**Abstract:** The quality of laser beam machining is the most important factor in laser cutting process. All cutting parameters might have significant influence on the resulting quality of work. In general, cutting parameters are adjusted and tuned to provide the quality of cut desired. But this consumes exhaustive amount of time and effort. Therefore, it is important to investigate the impact of cutting parameters on quality of cut. The aim of this study is to relate the CO₂ laser cutting parameters namely laser power, cutting speed, laser scanning speed. Laser cutting is a fairly new technology that allows metals to be cut with extreme precision. The laser beam is typically 0.2 mm in diameter with a power of 1-10 kW. Depending on the application of the laser cutter a selection of different gases are used in conjunction with the cutting. When cutting with oxygen, material is burned and vaporized when heated by the laser beam to ignition temperature. The reaction between the oxygen and the metal creates additional energy in the form of heat, supporting the cutting process. For certain well defined applications, e.g. cutting metal sheet using CO₂-lasers, suppliers of laser cutting machines provide a comprehensive database for process parameters.

**Keywords:** Laser Beam Machining, CO₂Laser, Process Parameters, Optimization

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## 1. INTRODUCTION

Most laser cutting carried out using Nd: YAG laser or CO₂ lasers. The general principles of laser cutting are approximately similar for both types of laser although CO₂ lasers dominate in the market. Laser cutting is a very new technology that allow metals to be cut with extreme precision. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. The world's first laser was demonstrated by Maiman using a ruby crystal (Maiman 1960).

Laser cutting is a common manufacturing process employed to cut many types of materials. Materials which may be cut included ferrous metal, non-ferrous metal, stone, plastic, rubber and ceramic. Laser cutting works by directing a high power pulsed laser at a specific location on the material to be cut. The energy beam is absorbed into the surface of the material and the energy of the laser is converted into the heat, which melt or vaporize the material. Additionally gas is focused or blown into the cutting region to expel or blow away the molten melt and vapor from cutting path.

There are several advantage of laser cutting over mechanical cutting, since the cut is performed by the laser beam, there is no physical contact with the material therefore contaminates cannot enter or embed into the material. Laser cutting can produce high quality cut, complex cut, cut several part simultaneously, produce clean cutting edge which require minimal finishing as well as low edge load during cutting which will reduce distortion.

The two main laser sources which are widely used in Laser cutting are CO₂ and Nd:YAG lasers. The latter having an advantage of shorter wavelength (1.06  $\mu$ m) which results in better absorption of laser energy in metals (Inconel, hardened steel, Titanium), metal matrix composites and ceramics without any coating. Most of the research works have been focused on the benefits of Laser cutting and addressed the challenges in conventional machining. The machining results of Laser cutting depend on both machining process parameters and laser parameters. The main operating parameters associated with laser assisted machining are: Laser power, spot diameter of the laser beam, cutting speed, feed rate and depth of cut. The optimal setting for Laser cutting is difficult due to the many control parameters and their interactions. A statistical study based on design of experiments is needed to investigate the effect of process parameter and their interactions. The present work aims to analyze the machinability characteristics with special reference to cutting forces and surface temperature of Inconel 718 at different cutting conditions using Taguchi method. The influence of cutting parameters namely cutting speed (s), feed rate (f) and laser power (p) on the workpiece surface temperature (Ts) and the cutting forces (Fx, Fy, and Fz) were analyzed using main effect plots. The Taguchi Methodology has been used in this study to arrive the optimal setting of laser machining parameters. In addition to this, the present work highlights the general benefits of Laser cutting compared with conventional machining.

The rest of this paper is organized as follows. Section 2 briefly reviews the literature on enablers of KM adoption in

SC. Section 3 presents the proposed method for ranking the barriers of KM adoption in SC. Empirical study is conducted and described in Section 4. Furthermore, discussion is described in section 5. Finally, conclusions are presented in Section 6.

## **2. LASER CUTTING PARAMETERS**

### **2.1 BEAM PARAMETERS**

These are parameters that characterize the properties of the laser beam which include the wavelength, power, intensity and spot size, continue wave and pulsed power, beam polarization, types of beam, characteristics of beam, beam mode. These are defined as:

#### ***Wavelength:***

The wavelength depends on the transitions in the process of stimulated emission with respect to the physical mechanisms involves in energy coupling and the process efficiency, stability and quality, the wavelength plays a most decisive role. It has important effect on material's surface absorptivity. For a specific material type, there is a certain wavelength which can have maximum absorption of laser energy with a lowest reflection. Due to the shorter wavelength of fiber lasers (in the range of 1  $\mu\text{m}$  almost the same as Nd-YAG laser) compared to CO₂ lasers (10.6 $\mu\text{m}$ ), it leads to the higher absorption in metallic material.

#### ***Power, intensity and spot size:***

The size of a laser system is usually specified in the term of power. The power of laser system is the total energy emitted in the form of laser light per second. Without sufficient power, cutting cannot be started. The intensity of the laser beam is the power divided by the area over which the power is concentrated. The high intensity of laser beam causes rapid heating of the material, which means that little time is available for heat to dissipate into the surrounding material. Additionally, the reflectivity of most metals is much lower at high intensities, compared to the low beam intensity. Moreover, the intensity determines the thickness of material which can be cut.

Spot size is the irradiated area of laser beam. In laser cutting application, it is required to focus beam into minimum spot size. Due to the better beam quality of fiber laser with very low divergence, the user can get spot diameters smaller than conventional lasers producing longer working distances.

#### ***Continuous wave (CW) and pulsed laser power:***

Both the continuous wave and pulsed laser power can achieve the high intensity needed for laser cutting. The cutting speed is determined by the average power level. Average power level with CW laser is higher compared to the pulsed laser.

### **2.2 PROCESS PARAMETERS**

These are parameters that characterize the properties of the laser beam which include focusing of laser beams, focal position and dual focus lens, process gas and pressure, nozzle diameter, stand-off distance and alignment, and cutting speed.

#### ***Focusing of Laser Beams:***

The focal length of lens is about the distance from the position of focal lens to the focal spot. In the fiber laser system, the laser beam is delivered by the fiber optics and use a collimator to form the divergent laser beam. After that, it comes to the focusing lens or mirror and it focuses the parallel laser beam onto the work piece. The cutting process requires the spot size is small enough to produce the high intensity power. The focal length of the lens has a large impact on size of the focal spot and the beam intensity in the spot.

#### ***Focal Position:***

In order to get optimum cutting result, the focal point position must be controlled. There are two reasons: the first reason is that the small spot size obtained by focusing the laser beam results in a short depth of focus, so the focal point has to be positioned rather precisely with respect to the surface of the work piece; the other one is differences in material and thickness may require focus point position alterations.

#### ***Process Gas and Pressure:***

The process gas has five principle functions during laser cutting. An inert gas such as nitrogen expels molten material without allowing drops to solidify on the underside (dross) while an active gas such as oxygen participates in an exothermic reaction with the material. The gas also acts to suppress the formation of plasma when cutting thick sections with high beam intensities and focusing optics are protected from spatter by the gas flow. The cut edge is cooled by the gas flow thus restricting the width of the HAZ. The commonly used gases are the oxygen and nitrogen. Nitrogen is mainly used for stainless steel and aluminum, whereas the oxygen is used for mild steel.

In the process of oxygen cutting, the presence of oxygen contributes to an exothermic reaction, which effectively increases the laser power. It results into high cutting speeds and the ability to cut thick material. When cutting thick material, the gas pressure must decrease with the increasing thickness, in order to avoid the burning effect, whereas the nozzle diameter is increased.

#### ***Nozzle Diameter, Stand-Off Distance:***

Nozzle is used to deliver the assist gas. The nozzle has three main functions in the laser cutting process: to ensure that

the gas is coaxial with the beam; to reduce the pressure to minimize lens movements and misalignments; and to stabilize the pressure on the work piece surface to minimize turbulence in the melt pool.

The stand-off distance, which is the distance between the nozzle and the work piece, is also an important parameter. The stand-off distance is usually selected in the same range as the diameter of cutting nozzle-between 0.5 and 1.5 mm-in order to minimize turbulence. A short stand-off distance provides stable cutting conditions, although the risk of damage to the lens from spatter is increased. The stand-off distance is optimized to maximum the cutting speed and quality.

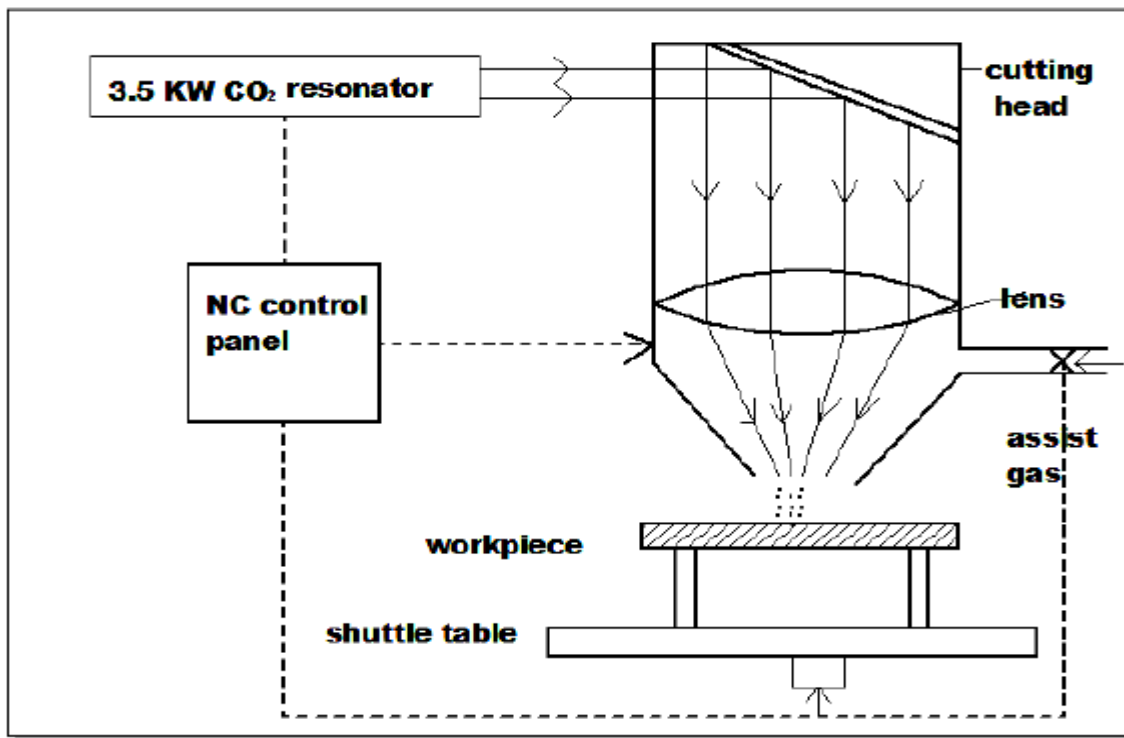
#### **Cutting Speed:**

The cutting speed must be balanced with the gas flow rate and the power. As cutting speed increases, the cutting time decreases and less time for the heat to diffuse sideways and the narrower the HAZ. The kerf is also reduced due to the need to deposit a certain amount of energy to cause melting. However, striations on the cut edge become more prominent, dross is more likely to remain on the underside and penetration is lost. When the cutting speed is too low, excessive burning of the cut edge occurs, which degrades edge quality and increases the width of the HAZ. In general, cutting speed for a material is inversely proportional to the thickness.

### **3. EXPERIMENTATION**

Al7075-10Wt%TiB2 metal matrix composite were prepared using Al7075 alloy and Al10%Ti, Al3%B master alloys. All three were melted together in a stoichiometric ratio in a 6kw of melting furnace (Graphite crucible is used for the process). Molten metal mixture was maintained at a temperature of 800°C for duration of 30 minutes. This is stirred for duration of 2 minutes at the interval of 10 minutes, using a mechanical stirrer which rotates at 300rpm. Chlorine based tablets were used for degassing of molten alloy and then it was poured into a 100*100*20 mm metallic mold.

Cast plates were then milled to a dimension of 100*100*5mm and subjected to laser beam machining operation. AMADA LCG 3015 CO2 laser cutting machine was used to carry out the experimental trials. It is an optic laser system, in which the cutting head moves in x, y and z axes to process the work piece. It consists of an advanced 3.5kw CO2 resonator and 7.5" lens. During the experimental trials power was maintained at 3500w, air was used as assisting gas and the nozzle diameter was maintained constant. Al7075 – TiB2 plates of dimension 100*100*5mm were used for the experimental trials. The schematic diagram of laser beam machine is as shown in Figure 1.



**Fig. 1. Schematic Diagram of Laser Beam Machining**

#### 4. PROCESS OUTCOMES

TABLE 1: Input and Output Parameters

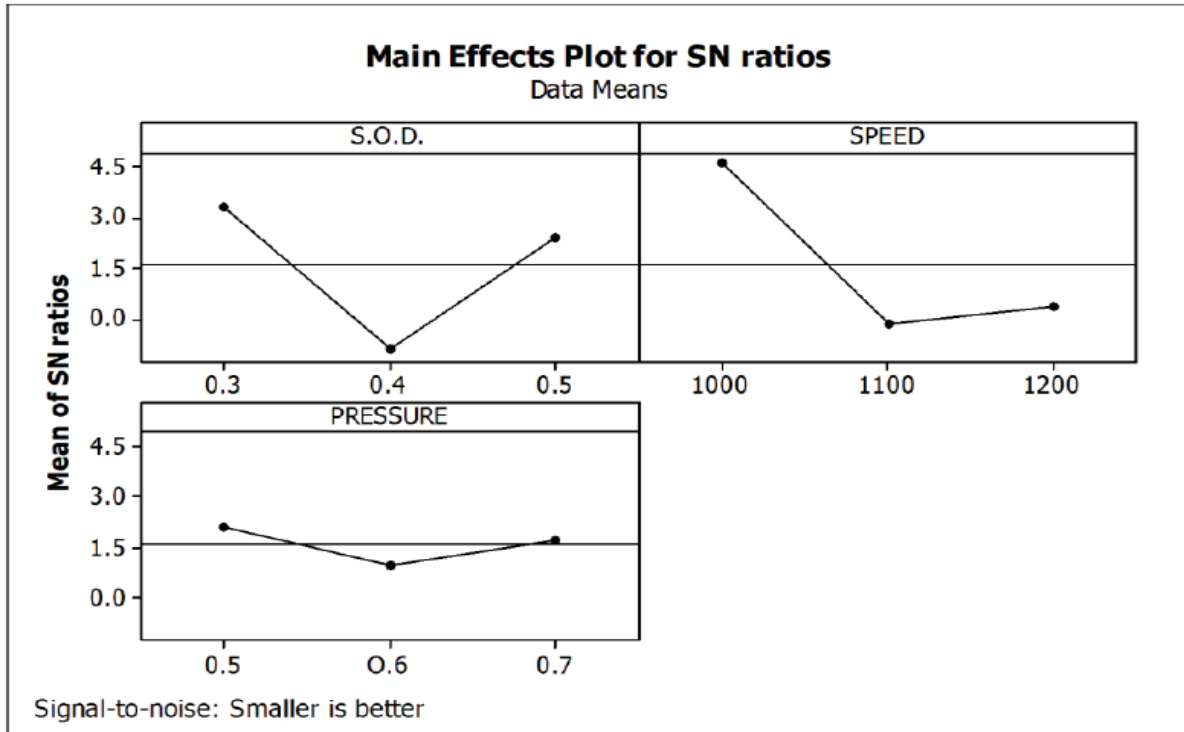
Sr. No.	Input Parameters			Output Parameters		
	Stand Off Distance (mm)	Cutting Speed (m/hr)	Gas Pressure (bar)	V.M.R.R. (m ³ /min)	Ra (μm)	Dimensional Error (mm ² )
1	0.3	1000	0.5	5480.14286	0.396	17.4404
2	0.3	1100	0.6	9227.83875	0.867	15.4433
3	0.3	1200	0.7	9149.298	0.922	17.0141
4	0.4	1000	0.6	7806.07204	1.002	17.9624
5	0.4	1100	0.7	6843.08102	1.163	17.5635
6	0.4	1200	0.5	6816.05776	1.171	18.2839
7	0.5	1000	0.7	6033.912	0.516	18.9827
8	0.5	1100	0.5	6844.41861	1.047	17.5278
9	0.5	1200	0.6	6827.12978	0.813	17.9888

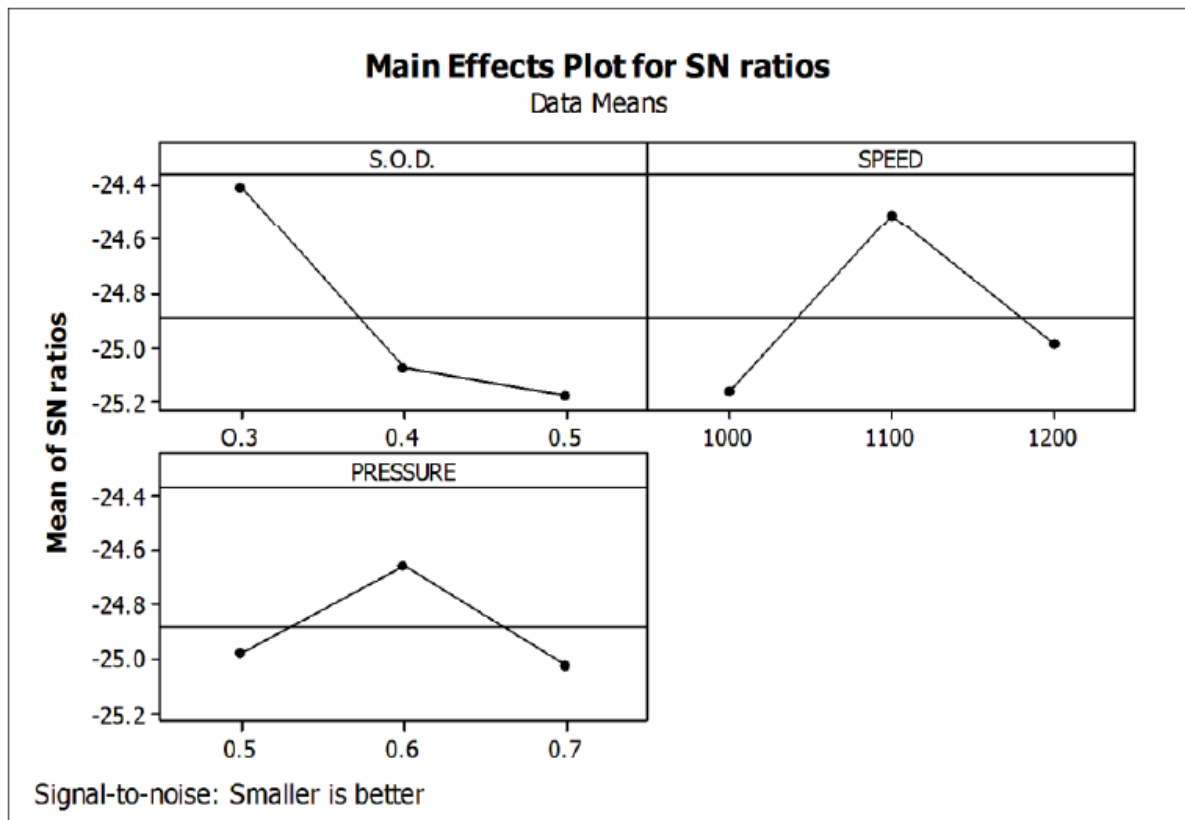
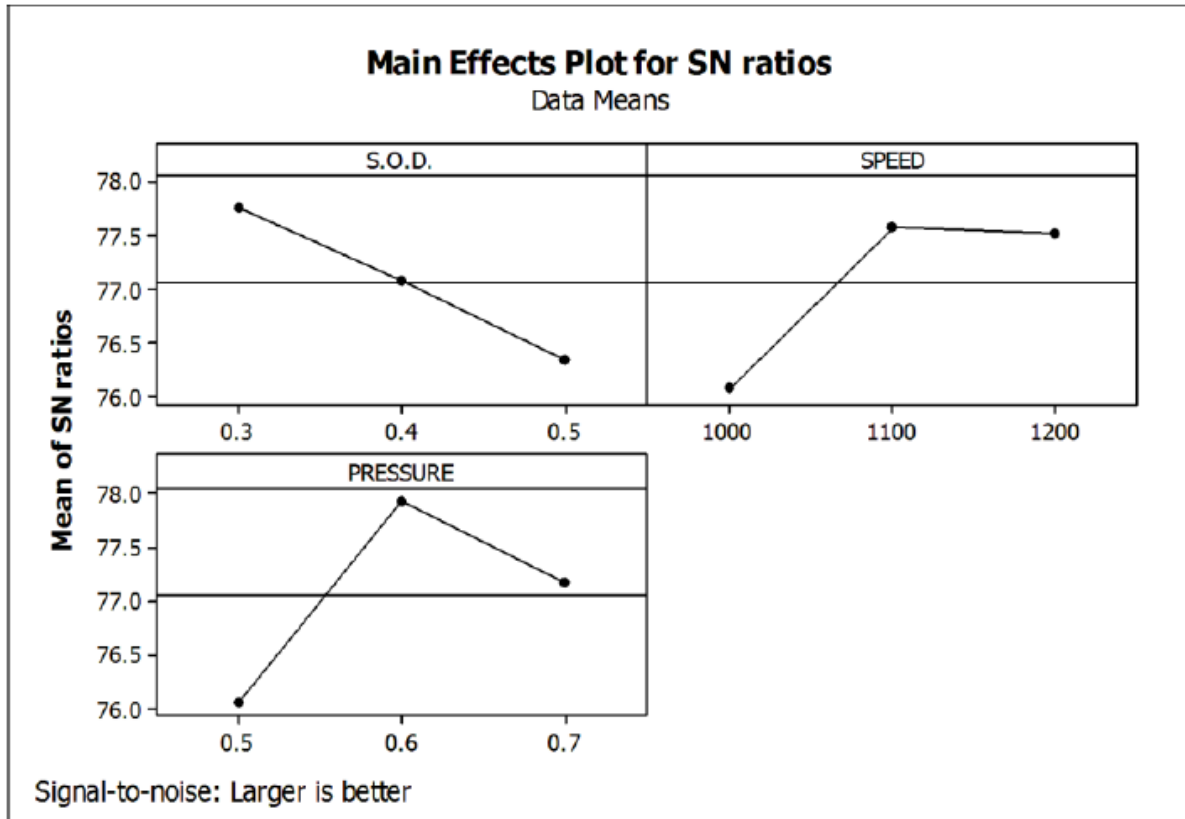
The above shown are the process parameters in the interaction. All output functions were then converted into signal noise ratio (S/N ratio) using Minitab software (version 16). This Taguchi technique have three condition for optimization i.e. smaller is better, nominal is better and larger is better. In this condition of LBM of Al7075 – TiB2, smaller the surface roughness, larger the volumetric material removal rate (VMRR) and smaller the dimensional error are the optimal conditions.

1. From the main effect plot for S/N ratio of surface roughness, it is clearly indicates that standoff distance (S.O.D) – 0.3mm, Cutting speed – 1000 m/hr, Gas

pressure – 0.5Bar, is the optimized condition which gives the minimum surface roughness.

2. From the main effect plot for S/N ratio of VMRR, it is clearly indicates that standoff distance (S.O.D) – 0.3mm, Cutting speed – 1100 m/hr, Gas pressure – 0.6Bar, is the optimized condition which gives the Maximum volumetric material removal rate (VMRR).
3. From the main effect plot for S/N ratio of dimensional error, it is clearly indicates that standoff distance (S.O.D) – 0.3mm, Cutting speed – 1100 m/hr, Gas pressure – 0.6Bar, is the optimized condition which gives the minimum dimensional error.







## 5. CONCLUSION

Al7075 – TiB2 In-situ composite were machined successfully using laser beam process as per Taguchi L9 orthogonal array; the optimized process parameters were investigated. Using analysis of variance (ANOVA) method significant process parameter for surface roughness, VMRR and dimensional error were identified. It is observed that, for surface roughness, cutting speed (56.38%) is most significant parameter followed by standoff distance (41.03%) and gas pressure (2.6%). For volumetric material removal rate (VMRR), gas pressure (42.32%) is most significant parameter followed by cutting speed (33.60%) and standoff distance (24.06%). For dimensional error, Standoff distance (53.34%) is most significant parameter followed by cutting speed (34.12%) and gas pressure (12.53%). The performance of optimum process parameters was confirmed by verification experiment.

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# A Review on Electrochemical Spark Machining

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**Abstract:** In this study, short and progress of electrochemical spark machining (ECSM) was developed to machine the micro-features like micropillar, microgrooves, micro holes, microchannels, etc. were developed. Materials can be machined regardless of material hardness, conductivity and strength by ECSM using electrochemical machining (ECM) and electric discharge machining (EDM) combination. Researchers developed electrochemical discharge, grinding (ECDG), milling, turning (ECDT) dressing, trepanning, wire ECSM, powder mixed ECSM, rotary ECSM, die-sinking ECSM. Magnetic field assisted in ECSM; vibration assisted ECSM methods. Pyrex, glass, stainless steel, soda lime glass, quartz, silicon, zirconium oxide, nitride, borosilicate glass, diamond crystals, E-glass/epoxy composite and silicon wafer were used as a workpiece. Effects of machining voltage and drilling depth on mean diameter, the influence of tool travel rate on groove width and depth and effects of voltage, concentration types on micro holes accuracy and machining verity were investigated. This review is to discuss the results of studies and applicability of this methods. It sums up also with a vision for future research in electrochemical micromachining.

**Keywords:** electrochemical spark machining (ECSM), electric discharge machining (EDM), micro-machining Electro chemical machining (ECM).

## 1. INTRODUCTION

The increase of utilization of microscale in the field of industry, science and technology fields promote to researchers to investigate more about the field of engineering. Electrochemical machining (ECM) use only for conductive materials, electric discharge machining (EDM) also for electrically conductive materials but electrochemical spark machine used for non-conductive materials and conductive with specific set-up capable of manufacturing of microscale products. This was new and hybrid methods to manufacture microscale conductive and non-conductive material both. Electrochemical spark machining (ECSM) is a combination of EDM and ECM was invented by (Suda and Kurafuji, 1968) but it first theory was given by physicists Hippolyte Fizeau (1819-1896) and Leon Foucault (1819-1868) [Fizeau and Foucault(1844)]. Fig 1 shows basic configuration of ECSM. Researchers developed a new technique, the same as EDM essentially. this technique removes material restriction(conductive and non-conductive) as well as also improve the material removal rate.

## 2. ECSM IN LITERATURE

Scientist tried to develop the ECSM new phenomenon before 1993. One of the main examinations on this, the impact of variation in voltage and electrolytes in 1993 by Raghuram et al., 1995

### 2.1 ECSM

MRR is totally depended upon voltage, so it was necessary to find the critical voltage. Basak and Ghosh, 1997

developed a model and compared numerical results with experimental result to find the metal removal rate. Ghosh, 1997 presented the basic principle and possibilities to improve the MRR of ECSM. Another work done by Bhattacharyya et al. 1977 work on other process parameters to improve the MRR, and find the, materil combination of both the tool to improve the MRR. Kulkarni et al., 2002 were the other researchers to investigate the mechanism of spark generation ECSM process. They paid attention to the relation among the time-varying current, rise of temperature and effect on MRR. A mathematical relation was developed to relate machining parameters with process criteria by Sarkar et al., 2006. They conclude that voltage was more effective parameter to effects the MRR heat affected zone and radial overcut. Chavoshi and Behagh, 2014 discussed and investigated the hole length, axial wear parameters and relation among them.

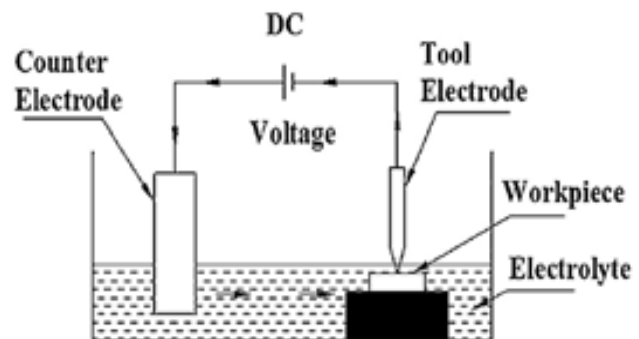


Fig. 1. Basic cell configuration in electro-chemical spark machining [Goud, 2016].

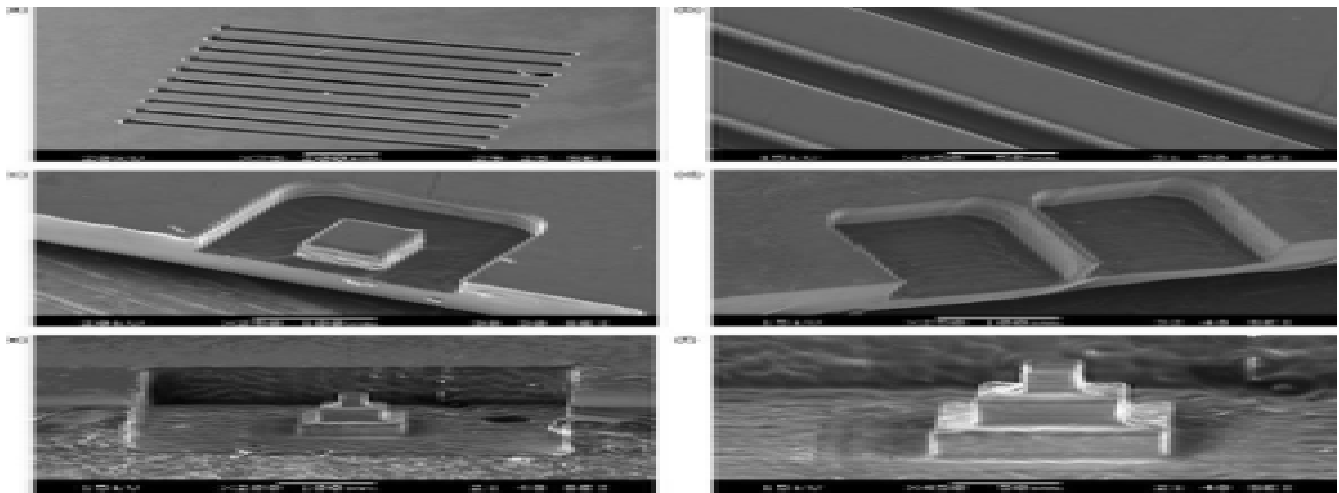
That results were shown by Coteate, 2011. Define parametre investigation for the borosilicate glass, and process parameters were optimized using Taguchi's method by Paul and Hiremath, 2013. Adding the surfactant electrolyte concentration, increased the current density and establishment of the current, hence improve the quality Laio et al., 2013. Hajian et al., 2016 describe the magnetic field orientation effect on ECSM and find that to increase the magnetic field orientation increase the surface quality and depth. Behroozfar and Razfar studied characteristics on the plasma channel, and material removal rate [A. Behroozfar, 2016] and tool wear [A. Behroozfar b, 2016] during ECSM. Dhanvijay and Ahuja, 2014 studied effective machining parameters of stagnant and method to flow of electrolyte on ECSM and results that electrolyte flow method had a high MRR, but a high diametric overcut that had been minimized. A mathematical model was developed by Kamaraj et al. [18] to predict the overcut of the surface that was important to protect the product dimensions. They also produced micro tools in-house and used them to drill glass.

Gupta et al., 2016 investigated the duty ratio and its effects on MRR, the depth of penetration, surface damage, and heat affected zone Gupta et al., 2016 studied that the effect of duty ratio on MRR, surface damage, depth of penetration, and heat affected zone. Ladeesh and Manu, 2016 focused on the effects of voltage, cycle time, duty cycle and percentage of electrolyte concentration on material remove rate with response surface methodology. Aspect ratio is also one of the subjects on ECSM like Gupta et al., 2016 investigated the effect of pulse duration on glass material. quartz is a type of glass; it has different characteristics from other. The effects of electrolyte, concentration and pulse properties on ECSM characteristics of quartz were investigated by Nguyen et al., 2015. Ladeesh and Manu, 2016 focused on the effects of voltage, duty cycle, cycle time and electrolyte concentration on material remove with RSM. Aspect ratio is also one of the conspicuous subjects on ECSM like.

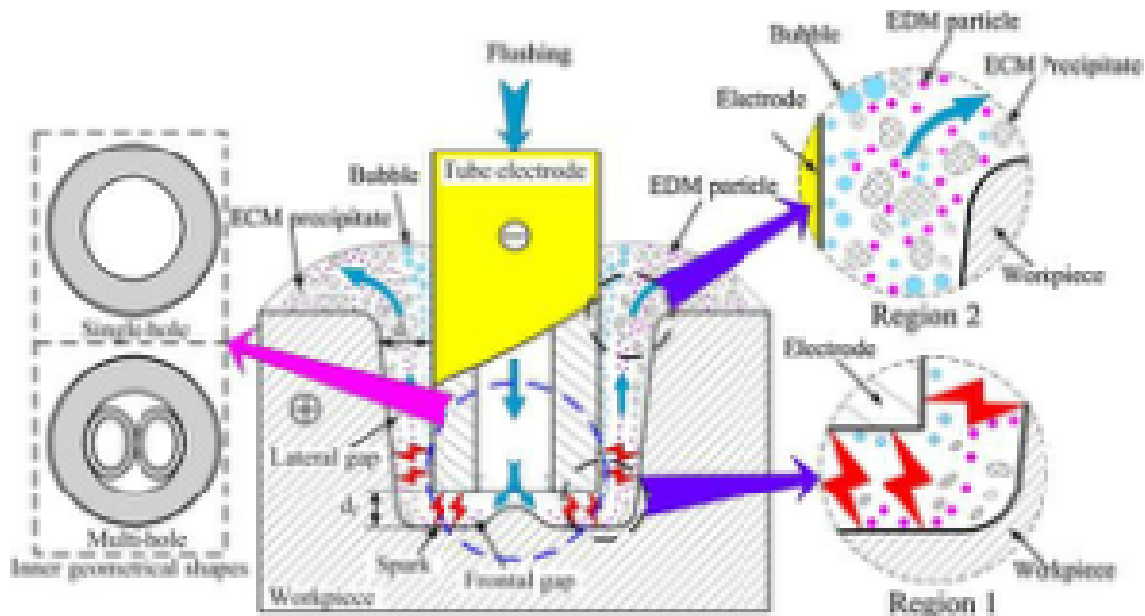
## 2.2 ECSM Hybrids

Sanjay et al., 2008 work on to develop new tools for electrochemical spark drilling to prevent the decrease on MRR with increasing machining depth. They used Spring-fed cylindrical hollow brass tool and spring-fed cylindrical abrasive tool were used To drill aluminum oxide ( $Al_2O_3$ ). Coteata et al. 2008 emphasize the effects of some parameters (the voltage, the electrode tool the diameter and the liquid density) on the electrode tool wear [Coteata et al. 2008], studied input parameters which effect on the tool wear And on the drilling speed [Coteata et al. 2009], the effects of the variation in voltage, The capacity of the electric circuit on tool wear [Coteata et al. 2011]. all parameter also designed, built and tested daily use equipment on ECDD process with passivating electrolyte [Coteata et al. 2016]. Nguyen et al., 2012 investigate the

simultaneous micro ED/EC milling the method which enhanced the dimensional accuracy and surface integrity to the situation that these methods used alone [Nguyen et al., 2012] and they studied analytical model to describe critically conditions for metal removal mechanisms for these methods [Nguyen et al., 2013]. Zeng et al., 2012 combined the methods, ECM for finishing and EDM for shaping had results that the size and shape of the workpiece was better compare to work on ECM only Liu et al., 2009 developed wire ECSM process to machine particle-reinforced aluminum alloy 6061 and work on to influence the current, pulse duration and electrolyte concentration on MRR. Results indicated that most effective factor for the highest MRR is the applied voltage/current. Again, they [Liu et al., 2013] developed a grinding-aided model to machine the reinforced metal matrix composites (MMCs). This new method enhanced the efficiency of machining and surface quality on MMCs. Also to find of critical breakdown voltage they developed a model [Liu et al., 2010] corresponding to experimental results. Cao et al. [33] machined 3D micro-structures within 100  $\mu m$  in size and find the good surface in spite of minimized structures (Fig 2). It was found that high voltage reduced machining resolution. Thus, they reduced required voltage using a load cell and the tool electrode with small layer depth. Cao et al., 2009 also used ECSM and micro-grinding process for machining of glass type material that had disadvantage, rough surface, using polycrystalline diamond (PCD) tool. Cheng et al., 2010 investigated the influences of the machining parameters on gas film quality which is the very important factor on machining quality. Again, they [K.Y. Kuo, 2013] used new process wire ECSM with electrolyte supplied in titrated flow to fabricate the micro-scale features. The results remarked that this new cost-effective and environmentally friendly process enable better machining outcomes with less width. They revealed [K.Y. Kuo, 2015] that adding SiC powder improved surface quality up to 80%. Finite element based model for ECSM drilling was developed to predict spark regime by Wei et al., 2011; Jiang et al., 2014 determined spark energy to model spark generation and this finite element model were validated with experiments. They B. Jiang, 2015 also modelled gas film evolution and validated with experiments to enhance the machining efficiency and quality. The properties of electrochemical spark effect were investigated by them [Zhang, 2016]. Razfar et al., 2014 studied effects of different types of longitudinal oscillation on machining speed and hole depth. Results revealed that although vibration did not effect on the process with micro drill, it was quite effective such as MRR up to 40% with cylindrical rod. Advantages of electrochemical spark drilling were revealed by Skrabalak and Stwora, 2016 on the comparison study drilling hole with electrochemical, electro spark and electrochemical spark drilling.



**Fig. 2.** (a) Micro grooves, (b) enlarged figure of micro-grooves (c) micro-pillar, (d) micro-wall, (e and f) micro-pyramid machined on glass by ECSM (KOH 30 wt%, 23 V pulse voltage, 1 ms/1 ms pulse on/off-time ratio, Ø 30-33 µm tool, 3 µm/s federate and 300 rpm rotational speed)



**Fig. 3.** Mechanism of TEHECDD for different inner geometrical shapes

Zhang et al., (2015); Zhang et al., (2015) b; Zhang et al., (2016); Zhang et al., (2016)b developed new process, tube electrode high-speed electrochemical spark drilling (TSECDD), shown in Fig 3, to machine cooling holes. Low-conductivity salt solution [Zhang et al., (2015)] enhanced machining surface and efficiency, increasing tube-electrode inner diameter increased MRR [Zhang et al., (2016)] on TSECDD. The performance of ECDD with super-high-pressure interior flushing [Zhang et al., (2015) b] and internal and side flushing Zhang et al., (2016) were investigated with machining parameters effects. Effect of tube electrode inner diameter on ECSM of nickel-based

superalloy which are widely used in aircraft engines were studied [Yan et al., 2016].

304 stainless steel was drilled with ECSM process by Huang et al., 2015 who established a new process using high-speed micro-electrode. Liu et al., 2015 analysed the inter-polar voltage and characteristics of current of a process using slotted metal wheel and mist-jetting electrolyte in ECSM to stabilize. Krötz and Wegener, 2015 developed a new process that was spark assisted electrochemical machining (SAEM). The process is shown in Fig. 4. This process was stimulating more contact arcs in

a period on the contrary of ECSM. This method presented that the finishing could be done with the same equipment. They also revealed [Krötz et al., 2013] that comprehending the heat distribution would enabled further improvement of this method. Electrochemical spark machining method was interested by some researchers [M.C. Panda, 2012; Rattan, 2017; Ziki and Wüthrich [2012]. Ziki and Wüthrich [2012] used spark assisted method for gravity-feed micro hole machining. They investigated tool wear and expansion for tungsten, steel and stainless electrodes.

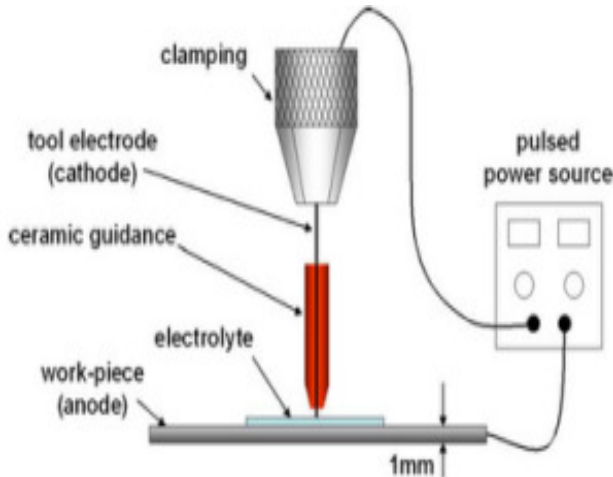


Fig. 4. Example of a One-Column figure caption

### 3. CONCLUDING REMARKS

The aim of this study was analysing the ECSM investigations and new processes of ECSM. Researchers, especially investigated and emphasized the material removal rate that was very crucial to improve the ECSM process. It was seen obviously that applied current [Liu et al., 2009] is the most effective parameter on MRR. New tools [Sanjay et al., 2008], tool shapes [Bhattacharyya, 1999] or new processes [Razfar et al., 2014, . Dhanvijay, 2014] were developed to enhance MRR. Besides, applied voltage is very effective on MRR [Sarka et al., 2006]. Yet, Cao et al., 2009 emphasized that high voltage reduced the machining resolution. Future works will be carried out in ECSM in the light of the results.

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# Factors Affecting Formation of Gas Porosity and its Effect on Mechanical Properties of A356 by Gravity Die Casting

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**Abstract:** Casting is a process which always faces a problem with one or the other defect. The majority of the defects occur in the casting are due to mold parameters, filling and during solidification. The metal in molten state come in contact with the atmosphere forming oxide on its surface. This oxide layer forms bifilms due to turbulence. This leads gas to get entrapped in the molten metal causing gas porosity in the casting. The gas entrapped in the casting during filling causes gas porosities during solidification. The study focused on identifying & controlling the parameters affecting formation of gas entrapment in molten metal called entrainment which result into formation of gas porosity. Taguchi's three factor 3 level DOE was used and effect of various parameters like, pouring temperature, degassing time and Volume in holding furnace on the formation of porosity and its effect on mechanical properties were checked. Experimental results interpreted that Volume in holding furnace is most effective for the mechanical properties as compared with the pouring temperature, degassing time.

**Keywords:** Bifilm, Entrainment, DOE, GDC

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## 1. INTRODUCTION

Casting process basically involves the introduction of a molten metal into a mold cavity, where upon solidification, the metal takes on the shape of the mold cavity. In case of aluminium casting, an aluminium oxide film in the mould within no time as the liquid aluminum is highly reactive with oxygen. The oxide films are often responsible for the failure of castings. The turbulence causes entrained films to get furled during the filling. It is thought that a furled, thin bifilm may be unfurled by the four main factors of hydrogen precipitation, dendrite pushing, shrinkage and inclusion. The unfurling phenomenon is important because it can affect and reduce the mechanical properties. Gravity die casting (GDC) has been one of the most economical and simplest ways of casting metals and alloys. The folding of the advancing front of the liquid metal causes many problems such as entrained air, bubbles and oxide bifilms.

This research paper focuses on optimising parameters like pouring temperature, degassing time and volume in holding furnace which affects formation of gas porosity and its effect on mechanical properties of A356 by Gravity Die Casting.

## 2. LITERATURE REVIEW

Derya Dispinar (2005) in this work found that bifilms are the initiator and hydrogen is only a contributor in the porosity formation process. D. Dispinar and J. Campbell (2004) found that bifilms are the initiator and hydrogen is only a contributor to the porosity formation process. D.

Dispinar and J. Campbell (2004) explained the purpose of study of reduced pressure test. W. D. Griffiths, A. O. Omotunde and R. Raiszadeh (2006) researched to understand the change in the behaviour of the double oxide film defects once they are formed, and their development with time. R. Raiszadeh and W D Griffiths (2006) suggested that the atmosphere within a double oxide film defect should be consumed by the surrounding Al melt in less than two minutes.

## 3. TAGUCHI'S DESIGN OF EXPERIMENT

Robust design is an "engineering methodology for improving productivity during research and development so that high-quality products can be produced quickly and at low cost" (Phadke, 1989). Dr. Genichi Taguchi bases his method on conventional statistical tools together with some guidelines for laying out design experiments and analyzing the results of these experiments.

## 4. EXPERIMENTAL SETUP

The experimentation work is performed in an alloy wheel industry manufacturing Alloy wheels of A356. Fresh ingots and chip, rejected wheels, rings and sprues are used for melting in gas fired furnace for around 1 hour so that the temperature of the melt reaches 750 – 780 °C. Then Fluxing powder is added to remove dross from the melt known as "Fluxing". Nitrogen gas is then purged into the melt to remove gas in the form of bubbles and slag is taken to the surface. This is known as "degassing". Melt is then hold for some time before it is poured in the die of gravity die



casting machine to make alloy wheels. Here along with the alloy wheels, tensile test bars are casted with the same set

of parameters. The wheels and tensile test bars will then be heat treated (T6) and sent for further machining.

**TABLE 1: Factors and its Levels for L9**

TC	PoT	DgT	VoH
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

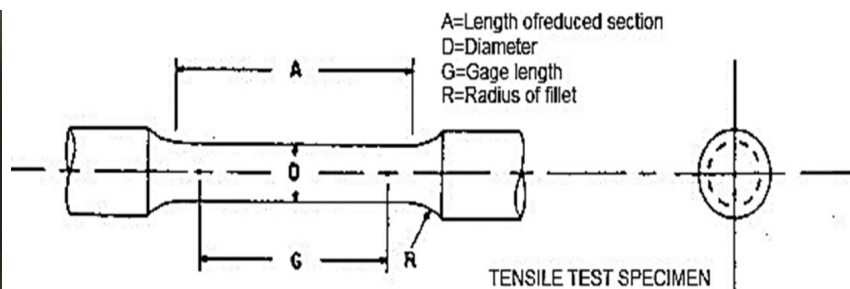
**TABLE 2: Factors and its Levels for L9**

TC	Test Sequence (Test Bar No.)	PoT (°C)	DgT (minutes)	VoH (S, M, E)
1	7	710	10	S
2	2	710	15	M
3	6	710	20	E
4	8	725	10	M
5	3	725	15	E
6	4	725	20	S
7	9	740	10	E
8	1	740	15	S
9	5	740	20	M

Experiments were performed and for each treatment conditions (TC) 6 tensile test bars of A356 were taken for each treatment conditions were taken using Gravity Die Casting machine. The test bars were then Heat Treated (T6). Density of the test bars were obtained by Archimedes Principle.

**TABLE 3: Chemical composition Alloy A356**

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cd	Al
Content	6.5-7.5%,	0.20% max.	0.20% max.	0.10% max.	0.25-0.45%	0.10% max.	0.20 % max.	0.05% max.	Remainder



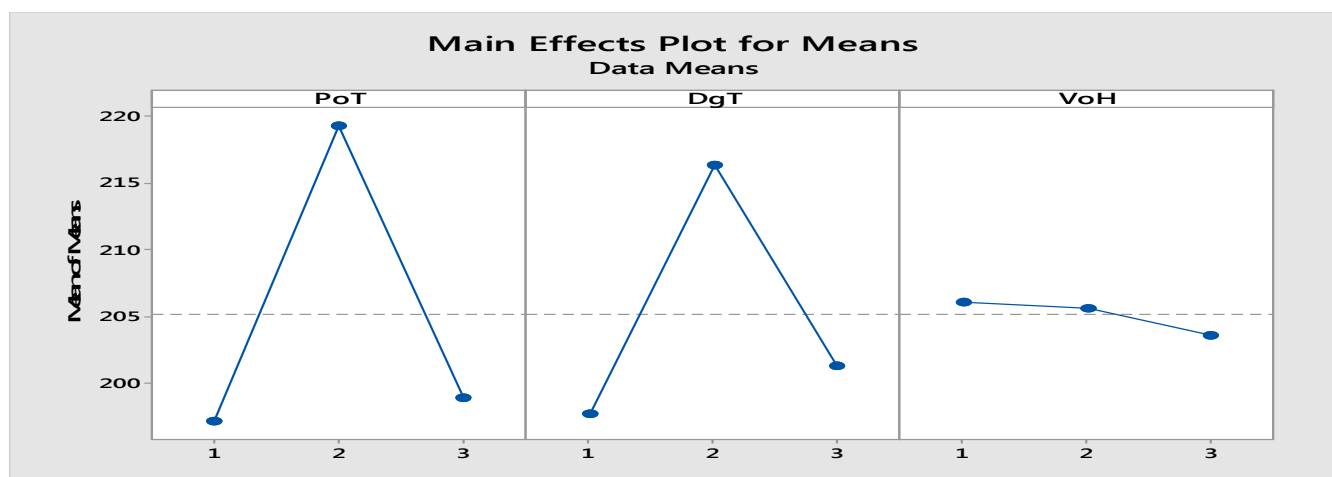
**Fig. 1. Tensile test Bar Specimen**

## 5. RESULT AND DISCUSSION

Calculations are for Larger the better (for making the system response as large as possible)

**ANOVA Table for Yield Strength**  
The ANOVA Results obtained by using MINITAB 17 were as below:

% Contribution			DOF	MSS	F-Factor	F CRITICAL	Significance
	C.F.	1136333				ALPHA=0.1	
	SST	15842.44	26				
17.21	SSPOT	2726.58	2	1363.28	2.40	2.59	NON SIGNIFICANT
11.15	SSDgT	1766.44	2	883.22	1.56	2.59	NON SIGNIFICANT
0.19	SSVoH	30.39	2	15.19	0.026	2.59	NON SIGNIFICANT
71.45	SSE	11319.02	20	565.95			
100							



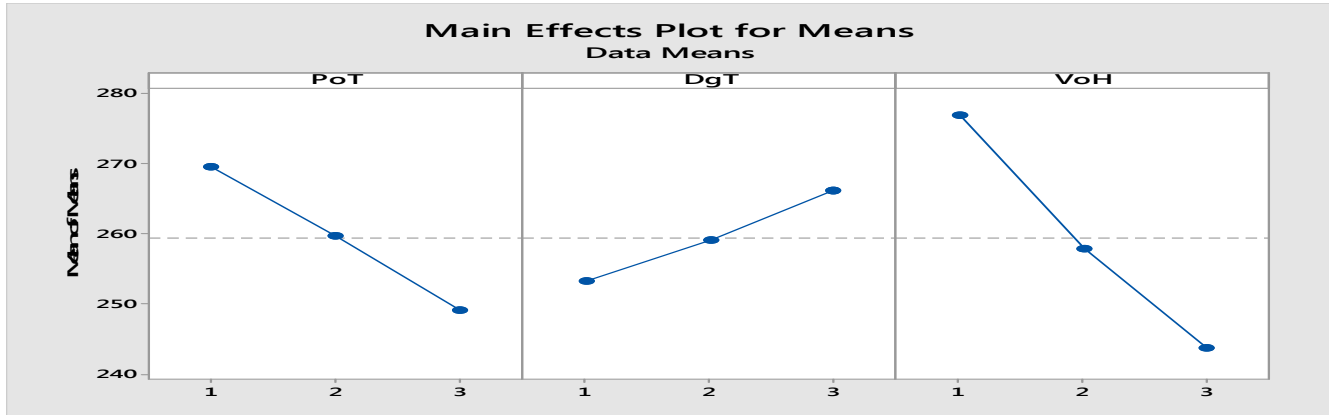
**Graphs: Factor Levels Vs Yield Strength**

Pouring Temperature, Volume of Holding Furnace & Degassing Time are NON SIGNIFICANT  
Interpretation from result: Ys, Yield strength does not depend on PoT, DgT and VoH

**Interpretation from result: Ys, Yield strength does not depend on PoT, DgT and VoH**

**ANOVA Table for UTS**

% Contribution			DOF	MSS	F-Factor	F CRITICAL	Significance
	C.F.	1817907				ALPHA=0.1	
	SST	13680.78	26				
13.54	SSPOT	1852.84	2	926.42	3.03	2.59	<b>SIGNIFICANT</b>
5.42	SSDgT	741.37	2	370.68	1.21	2.59	<b>NON SIGNIFICANT</b>
36.29	SSVoH	4964.39	2	2482.19	8.10	2.59	<b>SIGNIFICANT</b>
44.75	SSE	6122.18	20	306.11			
100							



**Graphs: Factor Levels Vs UTS**

Pouring Temperature & Volume of Holding Furnace is SIGNIFICANT, Degassing Time is NON SIGNIFICANT, Interpretation from result: UTS depends on PoT and VoH. It does not depend on DgT

**Interpretation from result: UTS depends on PoT and VoH. It does not depend on DgT**

**ANOVA Table for % Elongation**

% Contribution			DOF	MSS	F-Factor	F CRITICAL	Significance
	C.F.	1007.84				ALPHA=0.1	
	SST	101.07	26				
8.74	SSPOT	8.84	2	4.42	1.78	2.59	NON SIGNIFICANT
17.99	SSDgT	18.18	2	9.09	3.67	2.59	SIGNIFICANT
24.29	SSVoH	24.55	2	12.27	4.96	2.59	SIGNIFICANT
48.97	SSE	49.50	20	2.47			
100							

*Graphs: Factor Levels Vs % Elongation*

Degassing Time and Volume of Holding Furnace is SIGNIFICANT, Pouring Temperature NON-SIGNIFICANT, Interpretation from result: %Elongation depends on DgT and VoH not on PoT

**Interpretation from result: Ys, Yield strength does not depend on PoT, DgT and VoH**

**ANOVA Table for Density**

% Contribution			DOF	MSS	F-Factor	F CRITICAL	Significance
	C.F.	186.97				ALPHA=0.1	
	SST	0.061761	26				
29.34	SSPOT	0.02	2	0.009	22.71	2.59	SIGNIFICANT
1.52	SSDgT	0.0009	2	0.0005	1.17	2.59	NON SIGNIFICANT
56.22	SSVoH	0.03	2	0.017	43.51	2.59	SIGNIFICANT
12.92	SSE	0.008	20	0.0004			
100							

*Graphs: Factor Levels Vs Density*

Pouring Temperature & Volume of Holding Furnace is SIGNIFICANT  
 Degassing Time NON-SIGNIFICANT

**Interpretation from result: Density depends on PoT and VoH. It does not depend on DgT**

#### Summary of result From ANOVA

Properties	PoT	Level	DgT	Level	VoH	Level
Ys	N.S.	-	N.S.	-	N.S.	-
UTS	S	L1 (710 ⁰ C)	N.S.	-	S	L1 (Start/ Full)
%Elongation	N.S.	-	S	L3 (20 Min.)	S	L1 (Start/ Full)
Density	S	L1 (710 ⁰ C)	N.S.	-	S	L1 (Start/ Full)

*Summary of ANOVA table showing significance and contributions*

## 6. CONCLUSION

The study was carried out to understand the effect of bifilms on the quality of castings. Parameters affecting porosity in A356 alloy by GDC was identified and experiments were performed and the results are discussed. Taguchi's Design of Experiments gave the experimental data obtained for the test bars. Tensile tests were performed on the test bars and density test by Archimedes principle.

From the results obtained by the ANOVA table it was concluded that, Yield Strength is not affected by any of the factor. Two Factors are significantly contributing for UTS. PoT and VoH are significant whereas DgT is not significant. PoT should be at Level and VoH should be at Level 1. DgT and VoH are significant for the % Elongation. The DgT should be at Level 3 and VoH should be at Level 1. PoT is Non Significant for % Elongation. Two Factors are significantly contributing for Density. PoT and VoH are significant whereas DgT is not significant. PoT should be at Level 1 and VoH should be at Level 1. Degassing if it is done for more time even after the removal of gases from the melt, will not be effective as it has already removed the bifilms and gas in the form of bubbles. Rather it will be wastage of time and money. Two Factors are significantly contributing for Density. PoT and VoH are significant whereas DgT is not significant. PoT should be at Level and VoH should be at Level 1. For density it is clear from the results that the degassing time is not affecting the density means even if the degassing is carried out for 10 minutes (Level 1), the density will not be significantly affected.

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# A Review on Fabrication Techniques of Functionally Graded Materials

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**Abstract:** A Functionally Graded Material (FGM) is a (microscopically heterogeneous) composite material containing at least two different phases whose volume fraction change gradually along at least a dimension of the solid. Challenges of FGMs lie in the field of mass production, Quality control, and Cost. This report outlines review on Recent Advances in Functionally Graded Materials in terms of their manufacturing evolution. And it has been seen that future applications would be based on these smart materials which are supposed to serve us in adverse conditions.

**Keywords:** Functionally Graded Materials (FGM), Powder metallurgy, Centrifugal and Slip casting

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## 1. INTRODUCTION

Functionally graded material (FGM) which has compositional and microstructure gradient along its thickness has been introduced to be a potential solution of the problem of delamination which occurred at the interface during the fabrication of two or even more dissimilar materials when bonded together [Siti Nur Sakinah Jamaludin et al., 2013; Siti Nur Sakinah Jamaludin et al., 2013]. Microstructure, location-dependent, chemical agreement, or atomic orders are prominent factors that influence the property gradient in the materials. After controlling all these factors, the property gradient could be tailored to meet demand while having best utilization of the composite components [Lannutti JJ, 1994 and Shukla A et al., 2007]. Due to unavailability of proper fabrication method for the FGMs [Bever MB and Duwez PF, 1972; Shen M and Bever MB, 1972], we don't have that kind of outcomes which we have expected till date. To fabricate the FGMs specimens successfully researchers have focused on optimal combination of several methods [Kiebeck B et al., 2003; Miyamoto Y et al., 1999; Li JQ et al., 2003].

## 2. PREPARATION OF FGMS

We can have physical and chemical methods based on potential application, type of materials and available facilities for the FGMs fabrication [Schwartz M, 2002]. Classifications of the fabrication of FGMs have been done into four groups including bulk, layer, preform and melt processing [Miyamoto Y et al., 1999].

### 2.1. Powder metallurgy

Powder metallurgy is used for FGMs fabrication using solid materials. Steps of Powder metallurgy can be classified into four main types, particularly, powder preparation, powder processing, forming operations, and finally sintering or,

pressure assist hot consolidation [Siti Nur Sakinah Jamaludin et al., 2013]. It is capable of producing a gradient in a continuous manner or in a stepwise manner [S. Suresh, A. Mortenson, 1998]. The P/M approach is suitable for producing layer thickness of medium (100-1000micrometer) and large (greater than 1 mm thickness) and bulk FGMs with very good versatility in phase content can be fabricated [P. Czubarow, D. Seyferth, 1997]. The powder metallurgy technique is capable to produce FGM of a metal and ceramic combination; however glass-ceramic FGMs have also been seen [Victor Birman, Larry W. Byrd, 2007]. If a continuous profile is required, the wet P/M approach is suitable while if stepwise profile is required the dry P/M approach is sufficient. The various approaches which fall under wet P/M category are namely wet powder spraying [S. Suresh, A. Mortenson, 1998; P. Czubarow, D. Seyferth, 1997; Victor Birman, Larry W. Byrd, 2007; V. Cannilo et al., 2006], slip casting, centrifugal casting [Yeon-Gil Jung et al., 1998; Y. Watanabe et al., 2006; T. Ogawa et al., Y. Watanabe, S. Oike, 2005; 2006; R. Siva Kumar et al., 2003]. The Ceramic or Metal FGMs can be fabricated to reduce thermal stresses and find merits of the heat and corrosion resistances of ceramic and the mechanical strength, improved toughness, and decent machinability. It has been reported that powder metallurgy (PM) is the most significant method for mass production of these FGMs [M. S. EL-Wazery, A. R. EL-Desouky, 2015].

### 2.2. Hot pressing and cold pressing

Yttria Stabilized Zirconia (YSZ) and Nickel 20 Chromium (NiCr) are merged using YSZ NiCr FGM interlayer via hot pressing method [Li JQ et al., 2003]. Properties of FGM in term of comprehensive biocompatibility and bonding strength with bone tissue in the rabbit have been checked by *in vivo* studies [Chu C et al., 2006]. For  $Al_2O_3$ - $ZrO_2$  (Alumina Zirconia) FGM, the optimum processing

parameters for fabrication has been obtained by altering the compacting parameter ranged from 60 to 210 MPa, and of course the cooling/heating rate at many ramp/soak sintering cycle [Sun et al., 2008]. Very limited papers have been found on Nano size composition particles. Successful fabrication of Co/ $\alpha$ -Al₂O₃ FGM (composed of Nano size powders) has been accomplished using high pressure torsion procedure [Menéndez E et al., 2008]. This method is classified under powder metallurgy method and cold pressing because the sintering process is performed after the compaction.

### 2.3. Sintering process

It is very important to note that in cold pressing process, the sintering process is done only after the powders were being compacted. Three different sintering methods including electric furnace heating, high frequency induction heating and Spark Plasma Sintering (SPS) were studied [Watari F et al., 2003]. It has been reported that vacuum sintering is better than normal sintering. HAP/Ti FGM is the specimen that has been fabricated successfully under vacuum atmosphere [Marcelo TM et al., 2006; Dobrzanski LA et al., 2011; H. Feng et al., 2005].

### 2.4. Infiltration process

Infiltration process demonstrates the truth that micro components in YSZ/SiC FGM are possible to be fabricated via infiltration method [Hassannin H and Jiang K, 2010]. Infiltration or hydrology is the process by which fluid on the ground surface precipitates into the soil. The infiltration method has been used for certain FGMs with a complex shape preparation.

### 2.5. Centrifugal casting

Centrifugal Mixed-Powder Method (CMPM) is finally solution to the limitation of centrifugal casting method in fabricating FGMs containing Nano size particles [Watanabe et al., 2009; Gowtam DS et al., 2008]. Further study has been continued to a method called Reactive Centrifugal Mixed-Powder Method (RCMPM) which is able to produce better surface properties instead of controllable compositional gradients [El-Hadad S et al., 2009; Shimaa El-Hadad et al., 2010; Saiyathibrahim.A. et al., 2015]. A schematic of centrifugal casting method for FGMs fabrication and chemical composition gradient of cylindrical FGM was fabricated using centrifugal casting as shown in Fig. 1 [Minoo Naebe, Kamyar Shirvanimoghaddam, 2016].

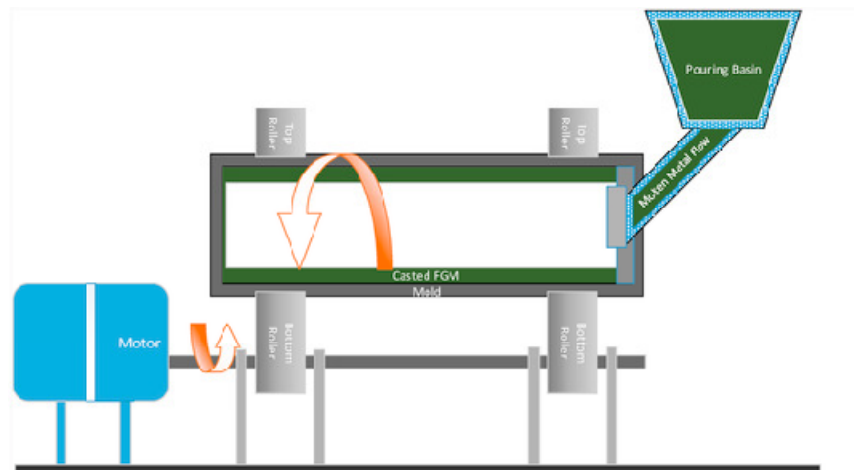


Fig. 1. Centrifugal Casting Method [Z.H. Melgarejo et al., 2008; M.R. Rahimipour and M. Sobhani, 2013]

### 2.6. Slip casting

Using the same method of slip casting, titanium foams with high purity and high strength macro porous elements were successfully fabricated within addition of emulsion process to stabilize the titanium [Neirinck B et al., 2009]. TZP/SUS304 FGM has been fabricated using slip casting technique [He X et al., 2008]. The gradual distribution of the chemical composition and microstructure of the fabricated samples will avoid the macroscopic FGM interface which use to happen in orthodox ceramic/metal

joint [Siti Nur Sakinah Jamaludin et al., 2013; Neirinck B et al., 2009; Katayama T et al., 2011].

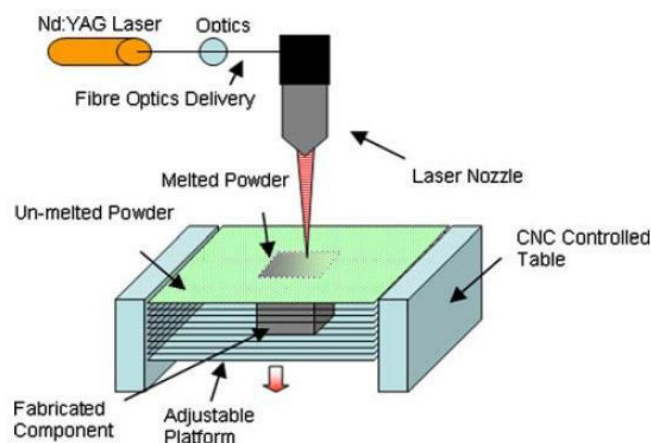
### 2.7. Thermal spraying

Thermal spraying is actually a technique by which the structure is coated with melted materials through spraying process. Here, the coating precursor will be heated either chemically or electrically. The advantage of using this technique is thick coatings (20  $\mu$ m to mm) over a significant area with high deposition rate which is thus better than the other coating process such as electroplating

and even vapor deposition [Siti Nur Sakinah Jamaludin et al., 2013; Kim JH et al., 2003].

## 2.8. Laser cladding

The suitable processing via Selective Laser Sintering (SLS) technique which is actually based on free-form concept parameters for the process of fabrication of polyamide 12 and Multi-Walled Carbon Nanotubes (MWCNTs) have been studied [Paggi RA et al., 2012].



**Fig. 2. Illustration of laser assisted processing using Nd:YAG laser power source (Mumtaz and Hopkinson, 2007)**

There is participation of high technology system in the laser cladding process particularly when the movement of the substrate and the other parameters need to be controlled by Computer Aided Design (CAD) system [Siti Nur Sakinah Jamaludin et al., 2013; Ouyang JH et al., 2002]. The Nd:YAG laser power type has been used in a fabrication via Selective Laser Melting (SLM) of super nickel alloy and zirconia functionally graded material as shown in fig. 2. The final materials involved an average porosity of 0.34% with a progressive change between layers beyond any major interface defects [Mumtaz and Hopkinson, 2007]. However, Laser rapid fabrication would be something else method made known to be under laser assisted processing [Siti Nur Sakinah Jamaludin et al., 2013; Ganesh P et al., 2009]. Researchers have applied various selective laser melting [H. Chung and S. Das, 2006], Laser Engineered Net Shaping [Kamran Aamir Mumtaz and Neil Hopkinson, 2007; M. L. Griffith et al., 1996; W. Liu and J. N. DuPont, 2003], Laser rapid forming etc.

## 2.9. Vapor deposition method

It is a technique in which materials in a vapor phase are supposed to be condensed to have a solid material. Vapor deposition is further being classified into two categories namely Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD). The processing sources determine the two distinctive methods beneath vapor

deposition process [Siti Nur Sakinah Jamaludin et al., 2013; Kim JI et al., 2003; Kim JI et al., 2005].

## 2.10. Additive fabrication method

Graded materials hold a significant place in the future of material engineering; the ability to engineer and thus fabricate products with material gradients using additive fabrication has offered improvement in structural performance, enhanced material efficiency, promoted material economy and thereby optimized material distribution [Markworth et al. 1995; Fan et al., 2000; Yang et al., 2002; Yeong et al., 2004]. Behind all such technologies, is the use of materials with homogeneous properties for prototyping as well as for fabrication purposes [Jacobs, 1992; Gibson & Shi, 1997; Weiss et al., 1997]. A detailed review of prior arts is given in [Oxman, 2011]. Hybrid layer Manufacturing (HLM) is used to fabricate anisotropic matrix. Many researchers have tried to develop this process but their main emphasis was to prepare the set up for this [Kieback, B. et al., 2003]. Few experiments have been done on the quality of the parts fabricated and the optimum processing parameters of HLM process [Kieback, B. et al., 2003; Song, Y., Park, S., Choi, D., Jee, H., 2005; Song, Y., Park, S., Chae, S., 2005; Gharibshahiyan et al., 2011]. It is seen that polymer matrix, ceramic matrix, metal matrix, and fiber reinforced are famous composites through Additive Manufacturing (AM) Technology. Application of AM technology is the missile nose cone which has ultra-high temperature ceramic graded to a refractory metal from outside to inside [Hussien A. Hegab, 2016].

## 2.11. Electrophoresis/Electromagnetic ways for FGM preparation

Electrophoresis and Electromagnetic separation are two latest emerging techniques of FGM fabrication. In current scenario these are attaining popularity because of their simplicity and low expenditures incurred while attempting for FGM fabrication [Siddhartha et al., 2009].

## 2.12. Impeller Dry Blending (IDB)

The study regarding IDB is first credited to A. J. Ruys [E. B. Douglas and J. John Moore, 2006] and his researchers. This method offers the capability of producing FGMs with an easy control of continuous gradient and compositions. The fabrication planning of Impeller dry blending can be divided in four steps: Feeding, Blending, Homogenization and Deposition.

## 3. FEW RECENT FABRICATION OF FGMS

Further a case study [Sinnott, S. B. et al., 1998] of CNT reinforced Al matrix has been discussed where wt % of CNT composition has been varied from one end to other surface. This FGM has light weight and has improved



resistive nature. Hardness variations within a layer were observed in this FGM with significant difference in heat conduction in the two directions [Sajan Kapil et al., 2014]. CNT is found as an effective reinforcement material in the case of composite material developments, because of its good physical and chemical properties [Iijima S., 1991]. The Functionally Graded Laminates (FGL) composites have been fabricated after incorporating CNT particles to aluminium metal matrix in various weight fractions, ranging from 0.1 to 0.5 wt% [Udupa G. et al., 2015].

#### 4. CONCLUSION

The paper outlines a review on various processes applied for fabrication of FGMs. The techniques include Powder Metallurgy (PM) Methods, infiltration and graded casting processes, thermal spraying, and laser assisted process and finally vapor deposition methods. It can now be said that the fabrication techniques of FGMs has advanced significantly. Few aspects have been highlighted as the challenges in developing innovative technique for FGMs preparation such as the suitability for mass production, the cost-effectiveness and the convenience level in controlling the quality. Finally, it has been concluded that the powder metallurgy as the most efficient method for the fabrication of FGMs in the future. The issue while using the PM method is the sintering process which should be further explored in order to attain improvement in the mechanical properties and microstructure of the manufactured FGMs.

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# Optimization of Process Parameters of Wire Electrical Discharge Machining: A Review

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**Abstract:** EDM is a very useful non-conventional machining process for electrically conductive materials which is advantageous over number of conventional machining processes in terms of quality and cost. It becomes difficult to achieve required quality of machining on EDM because it is running on number of controlling parameters. Only measurable combinations of given range of parameters gives good result for a given material. So by using different optimization techniques it is possible to achieve best combination. The process outputs like MRR, SR, kerf, TWR, cutting speed, hardness, surface finish are of more interest. This paper is focused on review of optimization of all such process variables of EDM process which gives collective information regarding parameters selection, Optimization technique to be selected, output of process, and workpiece material.

**Keywords:** EDM, Optimization, Process parameters.

## 1. INTRODUCTION

Electrical discharge machining (EDM) is a nontraditional, thermoelectric process which erodes material from the work piece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium. These electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric. The sparks occurring at high frequency continuously & effectively remove the work piece material by melting & evaporation. The dielectric acts as a demonizing medium between 2 electrodes and its flow evacuates the re-solidified material debris from the gap assuring optimal conditions for spark generation

EDM finds its application in machining of hard metals which can not be machined easily by conventional machining process. The main goals of WEDM manufacturers and users are to achieve a better stability and higher productivity of the WEDM process, i.e., higher machining rate with desired accuracy and minimum surface damage. However, due to a large number of variables and the stochastic nature of the process, even a highly skilled operator working with a state-of-the-art WEDM is unable to achieve the optimal performance and avoid wire rupture and surface damage as the machining progresses. Physical and metallurgical properties do not create any limitation for

the materials to be machined on EDM very popular in machining difficult-to-cut materials MRR can be referred as degree of production whereas surface roughness (SR) represents the measure of surface quality. Gap current (GC) is taken as a pulse of current to initiate cutting [2]. Various process performances of EDM are material Removal Rate, Tool wear Rate, Wear Ratio, Surface roughness, Recast Layer Thickness, Surface quality, kerf width, Dimensional accuracy.

## 2. OPTIMIZATION OF PROCESS PARAMETERS

Number of Researchers have used different optimization techniques to study parameteric variations namely, Taguchi methodology, Genetic Algorithm, Grey Relation Analysis, Box-Benkhen approach, Artificial Neural Network, Response surface Methodology, Artificial Bee colony algorithm, Harmony Search Algorithm, Particle swarn optimization, Bat Algorithm, Simulated Annealing, Regression Analysis, TOPSIS, Pareto optimization algorithm. Every technique is different and is having its own advantage. The process parameters like Pulse on time(Ton), Pulse off time(Toff), Peak current(Ip), Servo voltage(SV), Wire tension(WT), Wire Feed(WF), wire Feed rate, flushing pressure are mostly used.

In order to study parametric effect following data is presented

TABLE 1: Literature Review

Author	Material Used and Optimization technique	conclusion
M. Durairaj, D. Sudharsun and N.Swamynathan	W/p- stainless steel 304 Tool- brass wire of 0.25mm diameter Dielectric fluid-distilled water Methodology- GRA, Taguchi, ANOVA	ANOVA resulted that the Ton has major influence on the SR and Kw in both the Taguchi optimization method and Grey relational analysis.

Author	Material Used and Optimization technique	conclusion
R.Bobbili, V.Madhu and A.K. Gogia	W/p-ballistic grade aluminium alloy Methodology- Taguchi method coupled with GRA	-Ton, Ip and SV are significant variables to Grey relational grade. Optimum response characteristics such as MRR, SR and GC are improved with 6% error by employing Grey relational analysis
Chandramouli S and Eswaraiah K.	W/p-17-4 Precipitation Hardening Stainless Steel( PH Steel) Methodology- Taguchi experimental design (L27 orthogonal array)	-Ton and discharge current has most significant effect on both MRR and SR. Toff has least significant effect compared to other parameters. ANOVA reveals that Ton has highest percentage contribution for MRR (58%) and for SR (77%).
Pujari s. And koonaramji	W/p-aluminium alloy (2014T6 alloy) Methodology-Taguchi method, Hybrid GA	-Ton, Ip, spark gap voltage have significant effect on both MRR and SR. WT in SR, Toff and servo feed rate in MRR shown a significant effect
S. Kumar et al.	W/p-Ti-5Al-2.5Sn alloy Tool- copper-tungsten electrode Methodology-ANOVA	-Ip was observed to be most significant process parameter that badly affected the TWR. Cryogenic treatment of electrode material, Ton and flushing pressure also observed the significant factor. Insignificant effect of Toff was noticed on the TWR
Chinmaya P. et al.	W/p-Inconel 718 super alloy Methodology-QPSO algorithm, Taguchi's L27 orthogonal array, PSO	-Electrode material, discharge current and Ton are the important parameters for all the performance measures.MRR rate can be improved through the use of graphite tool but SR and ROC are seriously affected due to high discharge energy.
B. Kumar Lodhia and S. Agarwal	W/p- AISI D3 Steel Methodology-Taguchi methodology(L9 Orthogonal Array), ANOVA	-SR is most influenced by discharge current. Ton and current have influenced more than the other parameters
S. Tilekar and S. S.Das	W/p- Aluminum and Mild steel Methodology-Taguchi Method, ANOVA	-Spark on time and, input current are having significant effect in case of Al and MS. ANOVA result. Spark on time has major influence on SR for Al and input current for MS. Wire feed rate and Spark on time have significant effect on Al and MS respectively
A. Raj.D and Senthilvelan.T	W/p-Ti6Al4V Methodology-Box-Benkhen approach	-Ton and Toff are the important parameters that influences the SR. Toff is having major influence on MRR
V. Chengal Reddy, N. Deepthi, and N.Jayakrishna	W/p-Aluminium HE30 Methodology-Taguchi, GRA	-Combination of Ton, Toff, WT, lower flush and upper flush is essential to achieve maximum MRR and minimum SR and Kw.
Saravanan M et al.	W/p-Titanium Grade 2 (Ti Gr 2) alloys Methodology-Taguchi technique	-Gap voltage, WT and diameter of the wire are important factors in deciding the characteristic responses during the machining processes
V R Surya et al.	W/p-Al7075 Methodology-ANN	-ANN Predicted values of 70% correlates well with the measured values.
S.Tripathy and D.K.Tripathy	W/p- H-11 die steel Tool-copper Dielectric fluid- silicon carbide(SiC) Methodology-Taguchi, GRA	-When powder is added to the dielectric fluid, the surface topography is improved showing less defects and cracks. The surface texture showed tremendous improvement with reduced the RLT and improved the surface quality with the increase in Powder concentration
G.Ugrasen et al.	W/p -HCHCr Methodology-Taguchi, ANOVA	-Ton is having more effect on SR, accuracy and VolumetricMRR
M K Das et al.	W/p-EN31 tool steel Methodology-ABC algorithm, CCD, RSM	-With increase of discharge current and Ton and with the decrease in Toff and voltage MRR increases. Low values of voltage increases MRR and vice a versa. SR decreases with decrease in Ton, Toff, discharge current and an increase in voltage.
S S Nain, Dixit Garg and S Kumar	W/p-super alloy Udimet-L605 Methodology-Taguchi orthogonal L27 array, PUK kernel, non-linear regression and multi-linear regression, GRA	-Ton has more(60%) and wire feed has less(2%) significance on both MRR & SR
S Mohanty et al.	W/p- AlSiCp12% metal matrix composite (MMC) Tool- copper electrode of 99% purity	-Powders enhance the machining rate and surface finish.

Author	Material Used and Optimization technique	conclusion
	Methodology-Box Behnken design, PSO	
Vikas et al.	W/p- EN41 Methodology-Grey-Taguchi method(L27 orthogonal array)	-Discharge current has a larger impact on the SR
M K Das et al.	W/p-EN31 tool steel Methodology-ABC algorithm, CCD, RSM	-MRR and SR increases with an increase in current and Ton
P.Balasubramanian and T. Senthilvelan	W/p- EN8 and D3 steel Tool-Cast Copper and Sintered Powder Metallurgy Copper Methodology-RSM, ANOVA	-Significant factors for MRR and TWR-Ip, Ton and tool diameter for SR-Ip and Ton.
P.Raju and MMM Sarcar	W/p- 316L Stainless Steel Methodology-ANOVA	- Ton is significant for SR
A Bhatia and S Kumar	W/p – HcHcr Tool- Brass(0.25mm dia) Methodology-ANOVA	-SR is mostly affected by Toff
Vikas et al.	W/p - EN19 & EN41 Methodology-Taguchi	-Discharge current in case of the EN41 material and EN19 material had a larger impact as compare to other rocessing parameters on the MRR. MRR values in general for any particular combination of input parameters was higher for EN41 than in case of EN19.
A Goswami and J Kumar	W/p - Nimonic-80A Methodology-Taguchi's robust design methodology, ANOVA	-Workpiece is fairly machinable using WEDM Process.-For MRR and SR, % contribution of Ton is high and wire tension is low. MRR and SR increases with increase in Ton and decreases with increase in Toff
R Bobbili, V. Madhu and A.K. Gogia	W/p - aluminium alloy 7017 and rolled homogeneous armour (RHA) steel Tool- brass Methodology-ANOVA, Buckingham pi theorem	-MRR of machining is higher for materials with a low elting temperature and specific heat. The rise in Ton causes improvement in MRR and deterioration of surface finish. Wear rate of brass wire increases with increase in input energy leads to wire breakage.
B B Nayak and S S Mahapatra	W/p - deep cryo-treated Inconel 718 Tool- cryotreated coated Bronco cut-W(by Bedra), diameter 0.2 mm Methodology-Taguchi's DOE, maximum deviation theory, ANN, bat algorithm	-Composite score (0.9857) obtained from bat algorithm is superior than the predictive composite score value (0.7810) obtained from Taguchi analysis
K. Zakaria et al.	W/p - Iron-Copper-Tin(FeCuSn) hybrid metal material Tool- brass with a diameter of 0.25mm Methodology-Design of experiments	-Ton and Toff Voltage and Ip are more significant factor for both SR) and their hardness. high pulse-on time, high curr ent and high voltage produce worse surface quality. Hybrid metal materials are of more interested by the researchers
G. Selvakumar et al.	W/p -5083 aluminum alloy Methodology-Taguchi experimental design (L9 orthogonal array)	-CS was independent on WT and SR was independent on Toff and WT
D Thomas et al.	W/p -Tool Steel EN31 Tool-coated wires (zinc) Methodology-CCD, RSM	-Ton and Toff influences more MRR which increases and then decreases after a certain point. Current and WT have less influence as compared to Ton and Toff
P Sinha et al.	W/p-AISI D3 tool steel Tool-zinc coated wire electrode Methodology-Taguchi method, PCA	-servo voltage, Ton and IP are the significant factors for MRR, while IP and servo voltage are the significant for SR
M.R. Shabgard et al.	W/p-fine grain tungsten carbide(WC-Co) composite Tool-forged commercial pure copper Methodology-fuzzy-based algorithm	-MRR and SR increased with an increase in pulse duration and discharge current. Tool wear ratio decreased with an increase in pulse duration and discharge current
S Kuriakose and M.S. Shunmugam	W/p-Titanium alloy Tool- Zinc-coatedbrass wire(0.25mm)	-None of the solution in the Pareto optimal set is better than any other solution in the set.

Author	Material Used and Optimization technique	conclusion
	Methodology-GA, NSGA	
A Kumar et al.	W/p-Inconel 718 super alloy Tool- Brass Methodology-Taguchi design of experiment (L27 orthogonal array), ANOVA, SA algorithm,	-Voltage and Ton are more effective whereas current was less effective on both the kerf and the MRR
D Puhan et al.	W/p-aluminum silicon carbide composite Methodology-hybrid approach combining PCA, fuzzy inference system coupled with Taguchi method.	-hardness is increasing with increasing weight% of SiC in the composite and mesh size.Effect of weight percentage and mesh size of silicon carbide has relatively less contribution in improving multi performance characteristic
D. Devarasiddappa et al.	W/p-Inconel 825 aerospace alloys Methodology-ANN, Box Behnken experimental design	-Improved SR can be obtained at low levels of <i>Ton</i> and <i>SV</i> -Minimum SR is obtained with low <i>Ton</i> and higher <i>SV</i> . <i>Ton</i> is found highest influential factor on SR followed by <i>SV</i> and <i>Toff</i> ..
A Alias, B Abdullah and N M Abbas	W/p-Titanium Ti-6Al-4V Tool- Brass wire Dielectric-deionised water	-Machine feed rate play an important role in this experimental work. As the low kerf and the high MRR are equally important, equal machine feed rate are recommended.
P Shandilyaa, P.K. Jain and N.K. Jain	W/p-SiCp/6061 Al metal matrix composite (MMC) Methodology-RSM, ANN	-ANN models provide accurate prediction than RSM models when both are compared.Voltage is more significant parameter on average cutting speed than <i>Toff</i> and wire feed rate.
D.Sudhakara and G.Prasanthi	W/p-Powder metallurgical cold worked Tool steel Methodology-Taguchi L27 orthogonal array (OA), ANOVA	-The SR increases with increase in <i>Ton</i> and <i>IP</i> and decreases with <i>Toff</i> , spark gap set voltage and <i>WT</i> . The effect of water pressure is not very consequential.
J.B. Saedon et al.	W/p-titanium alloy Tool-Brass wire Dielectric -Deionized water Methodology-Taguchi, DOE, ANOVA, GRA	-Performance characteristics of the WEDM process such as cutting rate, MRR and SR are improved by using GRA
N Sharma, R Khanna and R D Gupta	W/p-HSLA(High strength low alloy steel) steel Methodology-GA, RSM, CCD	-The mathematical model is developed with the help of RSM. The percentage error between the predicted and experimental values lies in the range of $\pm 10\%$
K.D. Chattopadhyay et al	W/p- EN-8 Tool- Copper wire Methodology-linear regression analysis, Taguchi, ANOVA	- <i>Ip</i> and <i>Ton</i> are the most significant parameters for MRR and EWR, respectively. Peak current and electrode rotation are most significant parameters for SR. Increase in <i>Ton</i> , decrease in <i>Ip</i> and decrease in electrode rotation, improves SR
C. Gao et al.	W/p-PCD micro milling tool Tool- Zinc - copper wire Methodology-DOE	-For roughing operation, peak current and voltage pulse width are the dominant WEDM parameters; while for finishing operation, Peak current, peak voltage are the largest influence of parameters on cutting speed.
A Haşçalık and U Çaydas	W/p- AISI D5 tool steel	-The density of cracks in white layer increase with increased pulse duration and open circuit voltage. The SR increased when the pulse duration and open circuit voltage were increased
M.S. Hewidy, T.A. El-Taweel and M.F. El-Safty	W/p- Inconel 601 Methodology-DOE, ANOVA, RSM	-The volumetric MRR generally increases with the increase of the peak current and water pressure. Wear ratio increases with the increase of the peak current. SR increases with the increase of peak current and decreases with the increase of duty factor and wire tension.
K. Kanlayasiri and S. Boonmung	W/p- DC 53 die steel Methodology-DOE and regression model, ANOVA	-SR of the test specimen increases when <i>Ton</i> and pulse-peak current increases. A mathematical model was developed using multiple regression method
P. Sivaprakasam, P. Hariharan and S. Gowri	W/p- titanium alloy (Ti6Al4V) Methodology-CCD, ANOVA, GA, RSM	-Voltage, feed rate, interaction of voltage and capacitance have significant influence on MRR. The voltage, capacitance, feed rate, interactions of voltage and capacitance, voltage and feed rate have

Author	Material Used and Optimization technique	conclusion
		significant effect on Kw. voltage, capacitance, feed rate, interactions of capacitance and feed rate and have significant effect on SR.
G Talla et al.	W/p- aluminum/alumina metal matrix composite Dielectric- kerosene Methodology-Regression analysis	-PMEDM has better MRR when compared to conventional EDM process. Thermal conductivity, coefficient of thermal expansion and density of the material also significantly affect both MRR and Ra.
Dr.G.H.Gowd, M.G.Reddy and B.Sreenivasulu	W/p- SS304 Methodology-RSM, ANOVA	-Ton and Toff are most significant factors influencing all the responses
B Mathew, Benkim, J.Babu	W/p- AISI-304 Methodology-Taguchi GRA	-The grey relation obtained with experimental values poses less than 5% error with the predicted mean
B B Nayak et al.	W/p- AISI D2 tool steel Tool- coated BroncoCut-W Methodology-Taguchi's L27orthogonal array, TOPSIS, HS Algorithm	-Mathematical model is developed using non-linear regression analysis. Angular error, surface roughness and cutting speed were optimized to predict the optimal machining parametric setting and to know the effectiveness of HS algorithm
Jin Yuan et al.	W/p- chrome alloy Cr12 Tool- molybdenum wire of 0.17mm Dielectric- X-3 emulsified oil Methodology-GPR	-The experimental result shows that GPR models have the advantage over other regressive models in terms of model accuracy
S. Sarkar, S. Mitra and B. Bhattacharyya	W/p- $\gamma$ -titanium aluminide alloy Methodology-Taguchi method, ANOVA, Pareto optimization algorithm	-Surface roughness as well as dimensional deviation is independent of the pulse off time
Seung-Han Yang et al.	W/p- Steel Tool -copper prismatic Dielectric- kerosin Methodology-CPNN, SA	-A reliable function generated from counter-propagation neural network was employed to evaluate the non-dimensional multiple objective values.
U. A. Dabade and S. S. Karidkar	W/p- Inconel 718 Tool- Zinc coated brass wire Dielectric- Deionised water Methodology-Taguchi(L8Orthogonal Array), DOE	-Ton is the most influential factor for all the response variables such as MRR, SR, Kerf and dimensional deviation. SR improves with increase in Toff, WT and spark gap voltage.
R Chalisgaonkar and J Kumar	W/p-Pure titanium Tool-Zinc coated brass wire (0.25 mm) Dielectric- distilled water Methodology-Taguchi Method	-Enormous improvement in the capability index was realized by using the optimal process setting
N Sharma et al.	W/p- Cryogenic Treated D-2 Tool Steel Tool- Brass wire Methodology-integrated RSM and GA	-Ton has maximum effect on SR as compared to other process parameters. -The increase in Ton and servo voltage, SR increases. With the increase of peak current the slope of surface roughness curve observed to be declined
M Kumar and H Singh	w/p-Inconel X-750 Methodology-Taguchi's technique and GRA	-The cutting speed increases with the increase in pulse on time and peak current and vice versa. - CS decreases with the decreased value of SV and Toff
B Jakhar, P Katyal and V Gulati	W/p-Inconel 600(Nickel-based alloys ) Methodology-Taguchi's methodology( L-18 orthogonal array)	-CS is mostly affected by the peak current, Ton, Toff, and taper angle. - The surface roughness values (SR) are influenced mostly by peak current, pulse-on time, taper angle, pulse off-time, and dielectric flow rate
G K Bose and P Pain	W/p- OHNS Tool-Copper Wire with 0.25mm Diameter Methodology-Taguchi's L27 Orthogonal array	-Increasing the Ton, wire feed and WT values increases amount of MRR. Ton contribution is 50%. increasing the Ton, WT, wire feed values leads to a decreasing the amount of SR. most influential factor for SR is Ton. most influential factor for Overcut is wire feed



### 3. CONCLUDING REMARKS

Observing different parameters from various research papers, Pulse on time (Ton) has contributing more i.e.63%. Rest of parameters contribution is Peak current(33%), Pulse off time(25%), Servo voltage(17%), wire tension(11%), Discharge current(10%).

For maximum MRR, Kerf width, cutting speed and minimum Surface roughness and electrode wear rate, pulse on time is most essential parameter. Peak current is most influencing on MRR, Surface Roughness and Wear ratio, Pulse off time is most influencing on Surface Roughness and Cutting Speed, servo voltage is less influencing MRR and Surface roughness.

As per above study, different Work to hard materials and most of the composite materials can be experimented for various range of parameters.

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# Optimization of Infill Patterns for Spur Gear in 3D Printing using PLA

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**Abstract:** In the recent trends of rapid prototyping, all are going towards the additive layer manufacturing process. Most common technique of additive layer manufacturing is 3D printing. 3D printing is the process of making a physical component in the three-dimensional aspects, by generating many thin layers of material. In the 3D printer, any component is generated with different in-fill patterns. By changing the parameters, it resultant to change in the important parameters like strength and material cost. This research paper is to optimize the most economical infill patterns use in 3D printing which is fulfilling all required aspects. And develop a component in the lowest material consumption. Validating of the optimization method by comparing the physical properties, time consumption, cost of traditional manufacturing methods and additive manufacturing method.

**Keywords:** 3D Printing, Additive manufacturing, Performance evaluation, Optimization, Layered manufacturing, PLA

## 1. INTRODUCTION

In the present scenario of automation comes additive or advance fabrication in priority with 3D Printing technology. 3D Printing is nothing but it is just one more method of production with new geometry freedoms with more customized solutions through parameterized products. Working with the 3D printer is not that much complicated, 3D printer is just adding layer by layer until the CAD model will be made in real. 3D Printing technology can be economical for on demand as well as on location production with high accuracy. If the cost analysis for manufacturing of components with 3D printing cost with comparison with traditional manufacturing technology, 3D printing is not that much good for mass quantity production because in it the cost will uniform with quantity of product. The advantages are already proved with many of the researchers. The main advantages is that high number of component can integrate in one part with more resistant, good attachment and lightweight with high efficiency. It is mainly useful for prototyping, supporting parts and bridge manufacturing

## 2. METHODOLOGY

For the analysis and optimization of process parameters for infill patterns of PLA on 3D Printer after make many of the shape in 3D printer with different patterns. Spur gear is selected for optimized the patterns as it is complicated in shape as well as commonly use in daily life of mechanical side.

### 2.1 CAD Model

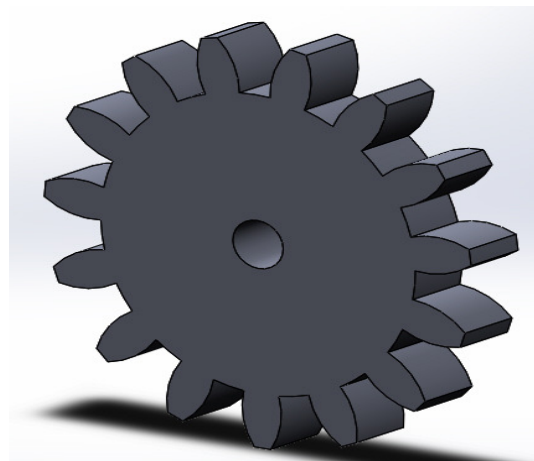
For fabricating any kind of part with the use of rapid prototyping or 3D printer technology first step is to make

the 3D cad model. All basic parameters are given in Table I.

**TABLE I: Basic Parameters of Spur gear**

Sr. No.	Parameters	Value
1	Module	4
2	Number of teeth	15
3	Pressure angle	14.5°
4	Face width	10 mm
5	Shaft diameter	8 mm

SOLIDWORKS 2016(Student Version) x64 Edition is used for CAD model of Spur gear. It is converted into STL file format for 3d printing as input file for slicing software Repetier-Host.



**Fig. 1. CAD Model of Spur gear**

## 2.2 Slicing of CAD model

3D printer read GCode File. Repetier-Host is been used for slicing purpose. Repetier-Host can directly slice the STL file with different layer patterns in Slice3r slicer engine and save in GCode file format. That file can directly input in the 3D printer with online as well as offline.

## 2.3 Layer Slices & Tool Path

Layer slices and tool path is the main thing in the 3D printer because of all the 3D printer, as well as many of the other advance manufacturing technology, also depends on it only. The G Code is one type of machine level program which controls the position of extrusion head with the reference of bed and it will give the instruction of steps that which path will be followed by all the component with reference to each other. It also controls other all parameters with layer by layer like fill density, the pattern of the top and bottom layer as well as other all the layer, temperature of extrusion and bed, feed rate and fill angle etc. And slicer is nothing but it is just one process which is making GCode from given configuration.

## 2.4 3D Object

3D printed objects are generally in between 50% to 80% stronger than another method of the manufacturing process. And if consider all other parameters like weight and strength even then also 3D printed object has great performance. Diameter of the PLA is taken 1.75 mm for the

3D print. Any of the object which is made with the use of PLA, properties of that depend on orientation as well as the closeness of path.

## 2.5 Software Configuration and Comparison

All the parameters shown in Table II kept constants while performing Experiments. Output results after slicing is given in Table III.

**TABLE 2: Constant parameters of sliced model**

Constant Parameters	Value/Name
Slicer	Slice3r
Layer height	0.25 [mm]
First layer height	0.35 [mm]
Vertical shells Perimeters	5
Horizontal shells of top and bottom	4
Top and Bottom fill pattern	Rectilinear
Fill angle	90
Extrusion multiplier diameter	1.3
Extruder temperature of first layer and other layer	200 °C
Bed temperature of first layer and other layer	70 °C
Feed rate	70 mm/min

**TABLE 3: Output Results of Slicing with Various Patterns**

Sr. No.	Gear No.	Slicer	Filament Needed	Fill density (%)	Fill pattern	Solid infill every(layer)	Testing	
							Weight (gram.)	Result (N/ mm2)
1	1	slice3r	14788	90	Line	2	26.818	281
2	2		9263	90	Concentric	2	31.445	364
3	3		13845	90	Octagram spiral	2	24.86	288.8
4	4		14531	90	Archimedianchord	2	26.957	429.2
5	5		14761	90	Rectilinear	2	28.241	465.6
6	7		14533	90	Hilburcurve	2	27	670
7	8		14843	90	Honeycomb	2	27.347	346
8	1A		14476	90	Line	0	27.496	470
9	2A		14277	90	Concentric	0	26.906	315.2
10	3A		13237	90	Octagram spiral	0	28.601	620
11	4A		14031	90	Archimedianchord	0	28.579	475
12	5A		14035	90	Hilburcurve	0	25.205	661.7
13	6A		14655	90	Honeycomb	0	27.827	312
14	1B		14382	80	Line	2	31.426	212.3
15	2B		14280	80	Concentric	2	22.397	261.5

Sr. No.	Gear No.	Slicer	Filament Needed	Fill density (%)	Fill pattern	Solid infill every(layer)	Testing	
							Weight (gram.)	Result (N/ mm2)
16	3B		13823	80	Octagram spiral	2	22.432	599.4
17	4B		14188	80	Archimedianchord	2	24.78	405.6
18	5B		14166	80	Hilburcurve	2	22.919	650.3
19	6B		14561	80	Honeycomb	2	23.87	265.9

### 2.6 Types of infill patterns:

Experiments have been carried out with different six solid infill patterns as shown in Figure 2. Rectilinear patterns work as solid layer patterns. First six prototypes are developed as per solid infill every 2 layer as given in Table 2.

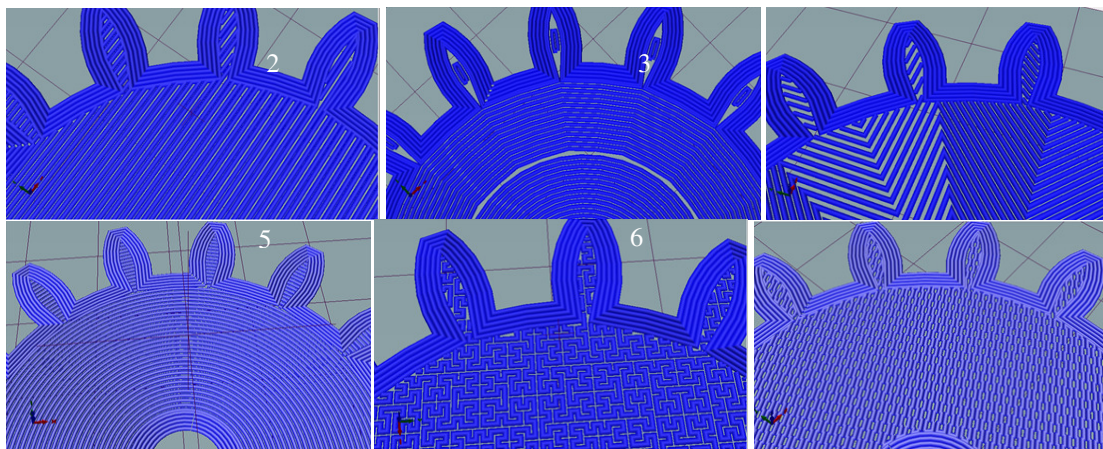


Fig. 2. Types of Infill Patterns

## 3. RESULTS AND DISCUSSION



Fig. 3. Prototype models of Spur Gear



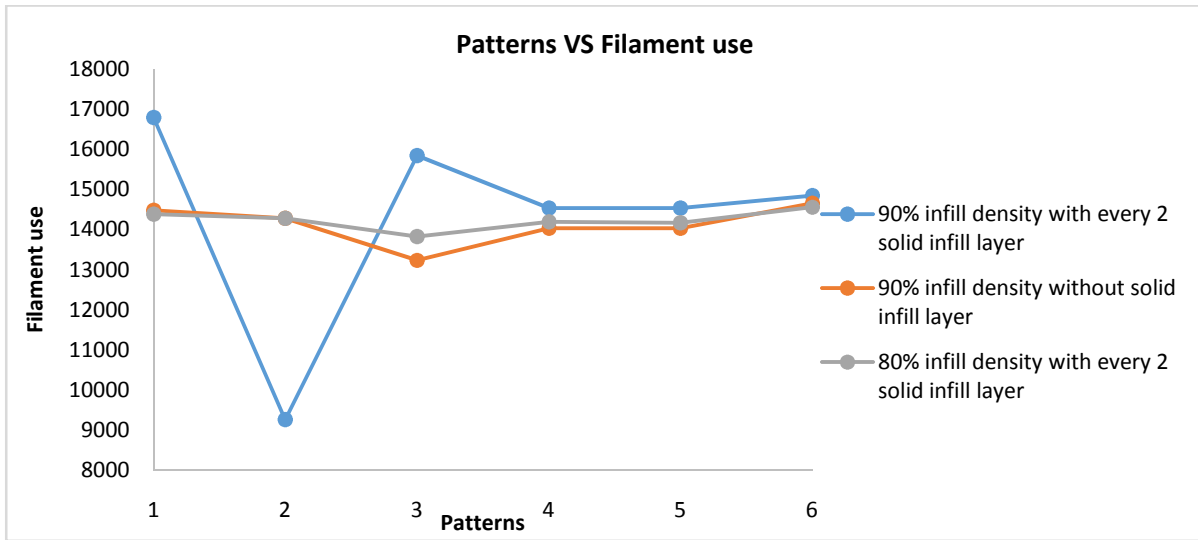


Fig. 4. Comparison of patterns vs filament use in different case of density

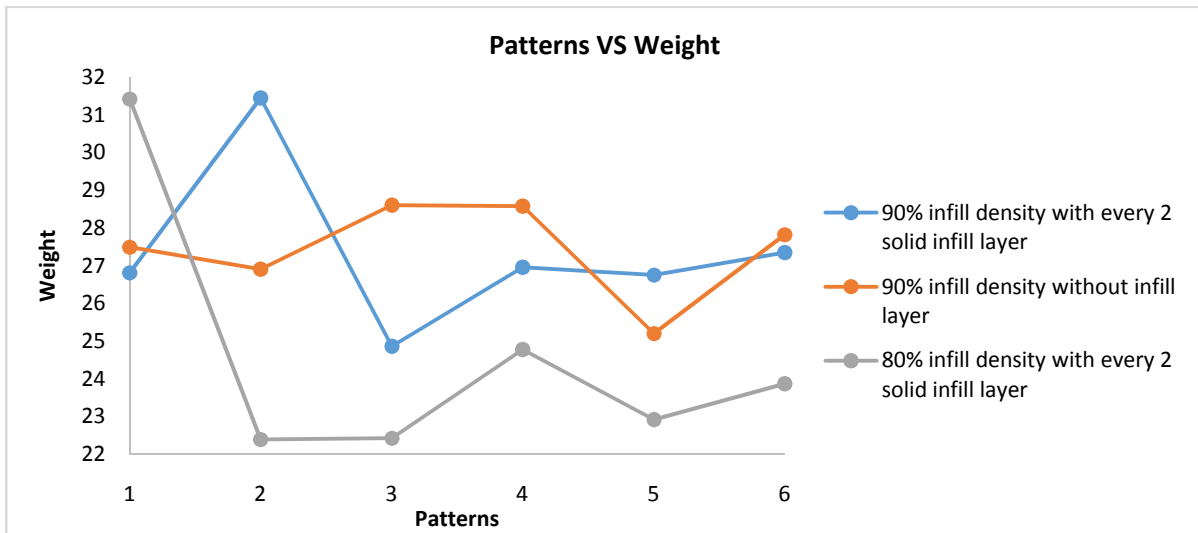


Fig. 5. Comparison of patterns vs weight of gears in different case of density

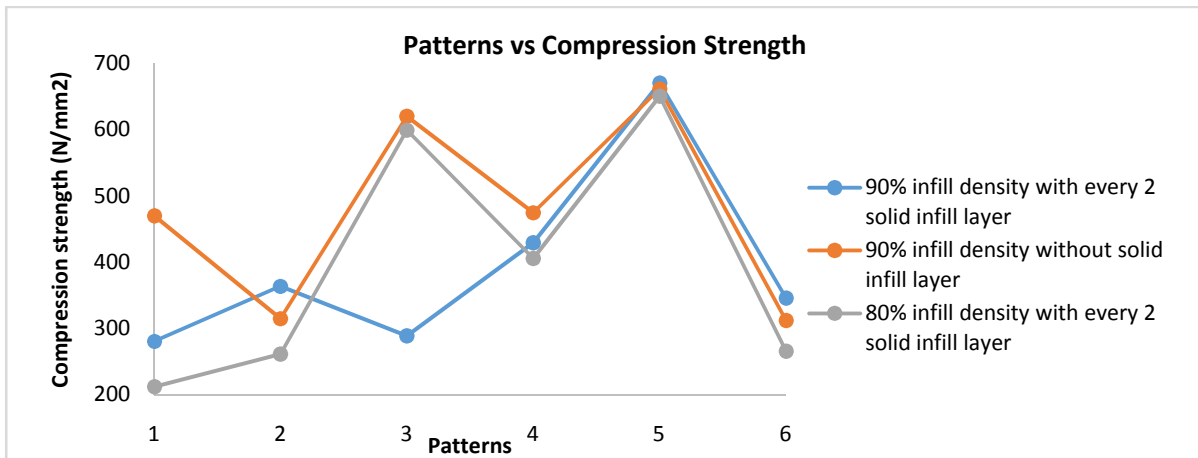


Fig. 6. Comparison of patterns vs compression strength of gears in different case of density

#### 4. CONCLUSION

This paper discussed about various patterns analysis. Hilburcurve patterns has more compression strength compare to the other patterns as shown in Figure 6. If density is same and without using any infill solid layer gives higher strength compare to the spure gear which is made with every two solid layer. For Hilburcurve there is no more change in compression strength if density of spur gear use upto 80% it reduce the weight of the gear as shown in Figure 4 and Figure 5. Maximum material use in case of Honeycomb patterns in each three case.

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SECTION – VI

PRODUCT AND PROCESS INNOVATIONS

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# Modification and Development of Two Wheel Pesticide Spray Pump to Overcome the Limitation in Traditional Pesticide Spray Pump

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**Abstract:** The main aim of this paper is to make modification in traditional spray pump which is operated manually i.e, hand operated spray pump. Hand operated spray have lot of limitations and we tried to overcome these limitations by making some modification in spray pump. Farmers are used manually lever operated knapsack sprayer because of its versatility, cost and design. But this sprayer have certain limitations like it cannot maintain required pressure, it lead to problem of back pain and tank capacity is low. We have proposed equipment that is wheel driven spray, it is a portable device and no need of any fuel to operate, which is easy to move and sprays the pesticide by moving the wheel. This wheel operated pesticide spray equipment consumes less time and avoids the pesticide coming from front of the nozzles which will in contact of the person who sprays pesticides. The mechanism involved in this spray is reciprocating pump, which is driven by the wheel.

**Keywords:** Manual operated spray pump, Two wheel operated, reduced back pain, wastage of pesticide.

## 1. INTRODUCTION

India is set to be an agricultural based country. Approximately 75% of population of India is dependent on farming directly or indirectly. Our farmers are using the same methods and equipment for the ages. E.g. seed sowing, spraying, weeding etc.

Agriculture sector is facing problems with capacity issues, labour shortages and increasing consumer demands. In addition, most farmers are desperately seeking different ways to improve the equipment quality while reducing the direct overhead costs (labour) and capital. There is need for development of effective spraying machine for increasing productivity. Thus a significant opportunity rests with understanding the impact of a pesticide spray pump in an agriculture field.



Fig. 1. Existing Spraying Method

Usually farmers are used two types of traditional spray pump i.e hand operated spray pump and petrol engine spray pump. By looking conventional spraying method of spray pump found some disadvantages. Hand operated spray pump requires a more power to create a sufficient pressure in piston for getting spray from spray nozzle. For that a person carry a spray pump on back side and simultaneously move a handle in upward and downward direction for creating a pressure by piston and move a spray nozzle where person are spraying on crop. So in that method a person carry a spray pump of 15 litre and simultaneously move handle upward and downward so that it create a body back pain problem of person and person are immediately tired. Similarly another type of pump used by farmer is petrol pump, in petrol pump have a tank of 20 litre and have a petrol engine of 8 kg. It also carry by a person on back side and weight of spray pump is more than hand operated spray pump. Petrol spray pump have a greater speed so that consumption of pesticide is more than hand operated spray pump because person walking speed is constant but the speed of spraying is greater and unable to adjust spraying speed by the walking speed of person so that the pesticide consumption is always more than the actual requirement. To overcome the disadvantages on traditional spray pump to design a two wheel driven spray pump. This two wheel driven spray pump itself carry a pesticide tank and no need to move handle in upward and downward direction. Two wheel carry a tank so it reduces the back pain. This two wheel driven spray pump do not require any fuel so it reduce fuel cost. The design spray pump run on the mechanism connecting a link to the shaft of piston. As the

wheel rotate, then the rotary motion of wheel is converted in to reciprocating by links. The multiple nozzles are connect on the front size of spray pump and it is adjustable according to the height of crop. A pesticide sprayer is a portable and increased tank capacity so result in cost reduction, labour and spraying time. It has a multiple nozzle so that it covers maximum area and nozzle adjustment prevents the pesticide drops come back to labour body. The design should be strong and convinient which implement work effectively.

## 2. OBJECTIVE

The objective of this paper is to design and modify a traditional spary pump which overcome the limitation occurred in traditional spray pum and available a standard modified spray pump to farmer which is using convinientle and easily. The advantage of this spray pump is to reduced the human effort and cost of fuel used in pump and it removes the problem of back pain. In this spray pump the utilization of pesticide in proper proportion to the speed of two wheel otherwise in fuel operated spray pump the pressure is not adjustable and the speed of person is constant so that the excess pesticide is come from nozzle and it is wastage of pesticide so this limitation is overcome by two wheel operated spray pump.

## 3. LITERATURE REVIEW OF THE PESTICIDE SPRAY PUMP

1. Sandeep H. Poratkar suggests a model of manually operated multi nozzle pesticides sprayer pump which will perform spraying at maximum rate in minimum time. Constant flow valves can be applied at nozzle to have uniform nozzle pressure.
2. Shivaraja Kumar suggests equipment that is wheel and pedal operated spray pump, it is a portable device and no need of any fuel to operate, which is easy to move and sprays the pesticide by moving the wheel and also peddling the equipment. Inthis equipment using reciprocating pump and there is a accumulator provided for the continuous flows of liquid to create necessary pressure for the spraying action.
3. VarikutiVasantharao studied the design and implementation of multiple power supplied fertilizer sprayer has been presented. The proposed system is the modified model of the two stroke petrol engine powered sprayer which minimizes the difficulties of the existing power sprayer such as operating cost, changing of fuel etc. The two stroke petrol engine has been replaced by a direct current motor and operated by the electrical energy stored in the battery attached to the unit. The battery can be charged by solar panel during the presence of sun. It could also be operated on direct current during rainy and cloudy weather

conditions. This system can be used for spraying pesticides fertilizers.

4. SHIVARAJA KUMAR says that fertilizers are applied to agricultural crops with the help of aspecial device known as a "Sprayer, " sprayer provides optimum performance with minimum efforts.By the invention of sprayers, this enables farmers to obtain the maximum agricultural output. A pesticide sprayer has to be portable and with an increased tank capacity as well as should result in cost reduction, labour and spraying time. In order to reduce these problems, there are a number of sprayer introduced in the market, but these devices do not meet the above problems or demands of the farmers.
5. Dr. S.K. Chaudhary says that By mechanization in spraying devices fertilizers and pesticides are distributed equally on the farm and reduce the quantity of waste, which results in prevention of losses and wastage of input applied to farm. It will reduce the cost of production. It will reduce the cost of production. Mechanization gives higher productivity in minimum input. Farmers are using same traditional methods for spraying fertilizers and pesticides. Equipment is also the same for ages. In India there is a large development in industrial sectors compared to agricultural sectors. Conventionally the spraying is done by labors carrying backpack sprayer and fertilizers are sprayed manually. The efforts required are more and beneficial by farmers having small farming land.

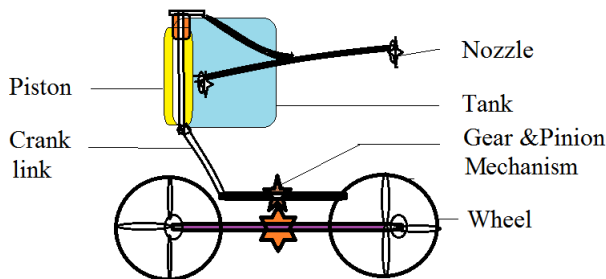
## 4. COMMON PROBLEM FOUND IN TRADITIONAL SPRAY PUMP

1. Heavy in weight causes difficulty in lifting manually.
2. The conventional spray pump having the difficulties such as it needs lot of effort to push the liver up and down in order to create the pressure to spray.
3. Another difficulty of petrol spray pump is to need to purchase the fuel, which increases the running cost of the spray pump.
4. Pumping to operating pressure is also time consuming moreover, very small area is covered while spraying.
5. During spraying the drops of pesticide come back on the body of person due to opposite direction of air so that it is dangerous to person.
6. Fatigue to the operator due to heavy weight.
7. Due to heavy weight during spraying, operator feel very tiredness and fatigue which reduces his efficiency.

8. Big size of pump cause inconvenience to the operator.

#### 4.1 Working principle of Spray pump.

Two wheel manually operated spray pump require only manual force (193.733N) to run the wheel, and normal human applying capacity 300N (newton) force. The wheel and the gear are mount on the same axel(1), the wheel is rotate that time the gear also rotate, the one more axel(2) is connect with the help of bearing above the axel(1), and the pinion is fitted on the axel(2) and this gear mesh with the pinion.



**Fig. 2. Mechanism of Two Wheel Operated Spray Pump**

The tank lever connect to the link and this link connect to the axel(2) due to that mechanism, the rotary motion converted into the reciprocating motion. The tank lever gives the reciprocating motion to the piston (in the tank) and piston is reciprocate in the cylinder due to this reciprocation the piston create the pressure (0.814 bar) at the one stroke. This pressurized fluid goes to the nozzle and

spray the dilute pesticide on the crop and it cover the more area than conventional spray pump.

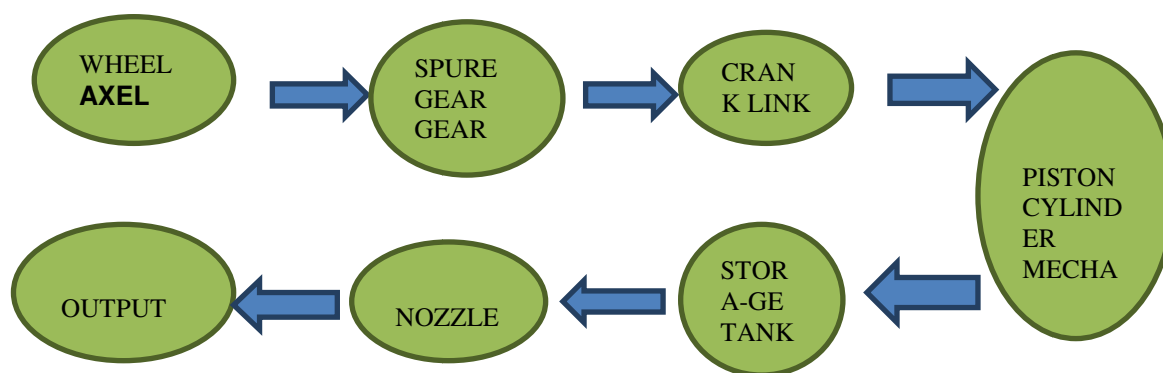
#### 4.2 Working Of design Spray Pump

Hand operated sprayer have the mechanical energy for spraying pesticides. The input is given through the lever to the hand lever operated sprayer and in prapose model input is manual force as soon as the wheel is drive. This portable spraying system consist of a tank and piston arrangement, gear pair, and crank shaft mechanism for converting rotary motion into reciprocating motion.

The assembly and spraying tank is mounted on chassis containing spraying solution. When push the assembly, the wheel rotated and rotary motion of wheel transfer to connecting links trough the gear pair, connecting link attached to piston of pump, provides reciprocating motion to pump which compress the fluid in tank there is a circular cross section on the bottom of the tank which compress the fluid in the tank by piston, due to this created a pressure which flows the fluid through the pipe contain inside the piston to the outlet and passes to the nozzle and create a spray of pesticide.

This sprayer has energy sufficient and easy to operate and maintain as it is flexible product with adjustable height of spraying nozzle thereis a greater flexibility for using it various crop. Since the two wheel required less space to move it can be used in a more versatile manner as compare to power sprayer and conventional hand operated spray pump.

#### Flow diagram of Working pesticide spray pump



**Fig. 3. Flow Diagram of Two Wheel Operated Pesticide Spray Pump**

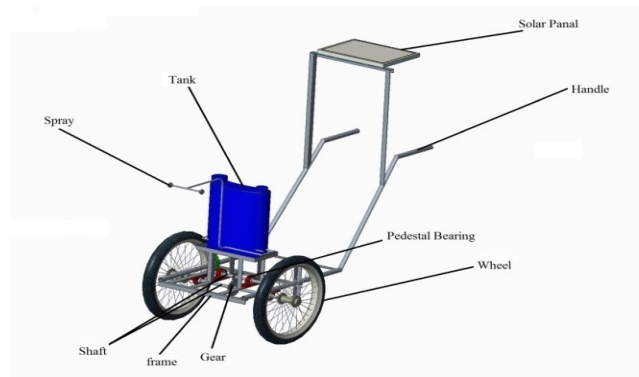
Steps involved in working of spraying machine

I. It works on the principle of compression of fluid by reciprocating motion of piston in cylinder.

II. Reciprocating motion of piston is achieved by rotating wheel axel with gear mechanism, as the piston and cylinder is connected with crank link.

- III. In piston cylinder, the fluid from storage tank is sucked in cylinder.
- IV. The reciprocating motion of piston increases the pressure of fluid.
- V. The high pressure fluid is discharged through nozzle.
- VI. The nozzle is provided to increase the fluid velocity and convert the fluid into spray.

## 5. CAD MODEL OF MODIFIED PESTICIDE SPRAY PUMP



**Fig. 4. CAD Model .f Modified Spray Pump**

## 6. DISCUSSION

We have developed and fabricated manually operated spray pump which is wheel driven. For this the detail analysis of the mechanism and the fabrication of the above said model is designed and developed. We have successfully tested this model and found the fare results as compare to the existing hand operated pesticide spray pump.

Technical features	Existing Pump	Modified Pump
Pressure	0.68 bar	0.814 bar
Discharge	1.2 lit/min	5 lit /min
Area cover	68 min/acre	35 min/acre
Number of full tanks required per acre	5.39	2.7
One single full tank cover area	750 sqm.	1100 sqm.
Crop	1 row	2 row

## 7. CONCLUSION

In this way we have used the two wheel operated spray pump for a spraying purpose by converting its rotary motion into reciprocating motion by piston in order to fulfill the needs of our farmers. The two wheel operated spray pump is ergonomically very useful to minimize the effort while spraying the pesticide, improve the performance and it reduces the fatigue of the operator. The

operator can cover large area in a short time without any additional energy by using the two wheel system. The manual energy can transfer to mechanical energy which conform the resources can be saved and system can be developed.

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# Flywheel Power Multiplication

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**Abstract:** This Paper deals with the concept of multi-hour electrical generation using flywheels manufactured either from the world of steel, rubber, plastic or hybrid glass. To rotate the 67 ton flywheel at 6000 to 7000 rpm, the design uses 5 numbers of 3000 kw motors (i.e. one motor for each flywheel) which are connected directly to the battery bank, with at least 15000 kw energy storage capacity is used as a backup support to look into the 5 independent motors constant electrical consumption needs throughout the specified programmed time. For power generation one 1500 kw PMG generator with 1000 rpm or less i.e. in between 1000 to 150 rpm is coupled and connected to 67 ton and 3 diameter flywheel. By rotating this flywheel at 6000 to 7000 rpm in max 10 seconds time and thereafter disconnecting the input energy to all the 5 independent motors by using timing sensors so that the 6000 to 7000 rpm fully charged flywheel connected with the generator is rotated continuously to 3600 seconds on the Plummer block bearings and generate energy is the innovation (input time is 10 seconds and output time is 3600 seconds). Here the 67 ton flywheel is rotated for 10 seconds using the power of 15000 kw motor there by the energy stored in the flywheel is very high, as a supplement back up help the design will use one 700 kw motor to support the continues rotations for max 6 hours at a stretch and this 15000 kw backup battery bank is getting the support from hybrid renewable energy combination applications for charging continuously. When renewable energy is not available to support then the discharging batteries using the stored energy to continuously support and run the motors connected to rotate flywheels then back to back charging technology is used to continue power generation process without any stop. When we purchase the new batteries i.e. new batteries are completely full and 100% charged there by the first hour available power is free, because all the motors are connected directly to this battery bank and this stored energy available is constantly used to rotate the series of motors connected to series of flywheels in a loop is the design process. By using 10 seconds input energy from the fully stored battery bank each set of 67 ton flywheels are rotated to maximum 6000 to 7000 rpm Example: - time taken to come down from initial 6000 rpm to 3000 rpm is minimum 1 hour gap so nearly 3600 seconds is the free energy generated by using only 10 seconds as input energy. As soon as the sensors notice the 3000 rpm once again 10 seconds is used to take the 3000 rpm rotating flywheels back to 6000 to 7000 rpm. From 3600 seconds fully charged battery bank @ of 10 seconds usage this battery bank will support 360 times to rotate 67 ton flywheels and generate free green electricity. Like this the power generation is continuous without any interruptions because the battery banks are continuously charged every hour and all 365 days.

Example for 67000 kg and 3000 rpm calculations

Force (Newton's) 9921524820

(kg) 1011713760.33

Surface Speed (m/sec) 471.29

Inertia ( $\text{kg} \cdot \text{m}^2$ ) 150750

Joules 7441143615

Kwh 2066.98 output

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Example for 67000 kg and 6000 rpm calculations

Force (Newton's) 39686099280

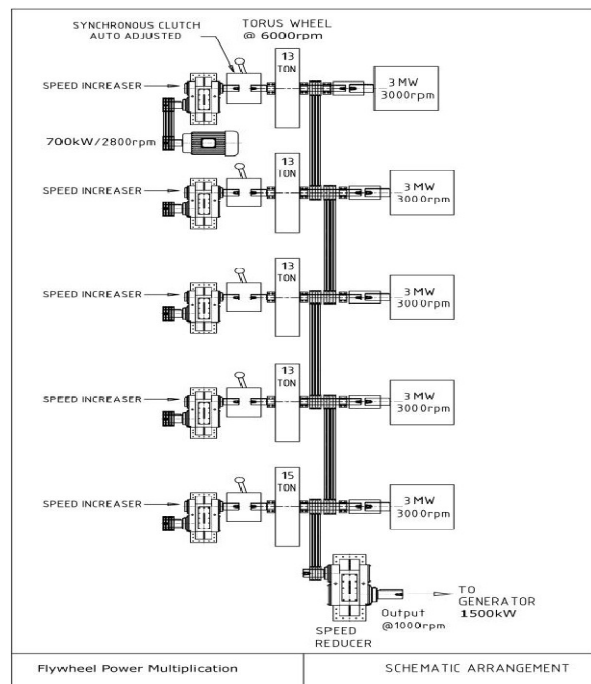
(kg) 4046855041.34

Surface Speed (m/sec) 942.59

Inertia ( $\text{kg} \cdot \text{m}^2$ ) 150750

Joules 29764574460

Kwh 8267.93 output



i.e. Total there will be 360 sets or just the 1st set will use 360 times from the available stored energy in the battery banks. The batteries have total one hour storage capacity including the calculated motor surge capacities. Each one complete independent set of 67 ton flywheels are rotated in vacuumed area within the first 10 seconds time and reach very high Rotations to 6000 to 7000 rpm. Initially after reaching 3000 rpm full load is applied, there after the flywheels will still continue to accelerate and reach 6000



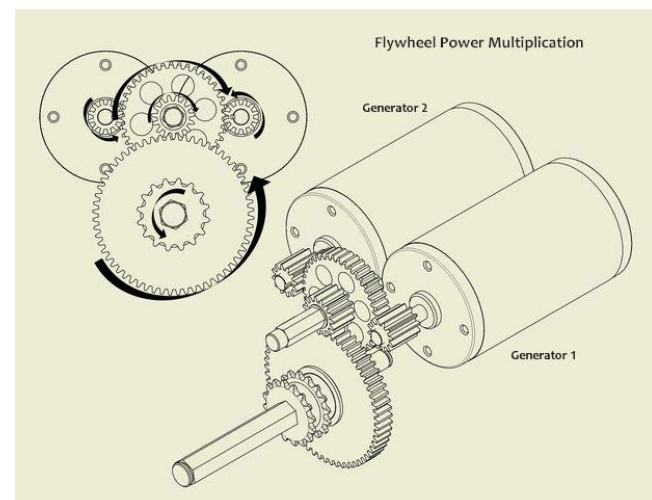
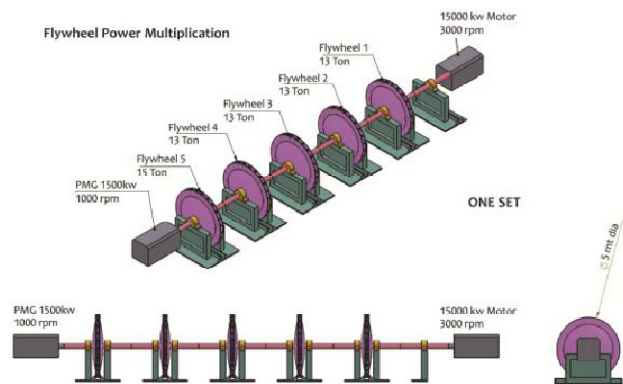
rpm or max 7000 rpm and become stable by using a speed increasing gearbox there by the total 5 wheels cumulative rpm will be 30000 to 35000 rotations in 10 seconds and by using a speed reducing gearbox connected to the last 5th flywheel i.e. input shaft speed is 6000 to 7000 rpm and output shaft speed is minimum 1000 to maximum 150 rpm ( i.e. we can use low rpm generator) there by the rotations of flywheel shaft and generator shaft are always matching. There by constantly maintaining the flywheel and generator rotations without any drop in the rpm, HZ, voltage etc and the power generated by the generator is either connected to the grid or used for any sector in house applications used as off grid applications for overall human development and useful for generating green electricity in outer space applications

**Method:** kindly treat this citation as an Example. Each kw design is tailor made: In this paper we are describing 1500 kw power generation method, The applied load is 1500 kw

We take 5 motors of same capacities example:-3000 KW (5 numbers) and 700 kw (1 numbers as back up to support the rotations) entire energy supply capacities are supported only by using battery bank backup. Total battery bank capacity of 15000 kw energy storage having 3600 seconds continuous supply capacity, out of this just 10 seconds power is consumed per each cycle for one independent complete power generation set of 67 ton flywheel and 1500 kw low rpm generator machinery thereby we can generate energy every hour from 360 identical sets because each set is using just 10 seconds time from the total energy stored for 3600 seconds. For every one hour the discharging batteries which are helping the entire 360 sets of motors to rotate 360 sets of 67 ton flywheel with 3 diameters ( example 13 ton wheel, 5 numbers) connected to 360 sets of 1500 kw

generators are again once again recharged by using any renewable energy systems to drive a series of flywheels arranged in cascade or series or in parallel and connected to series of independent gearboxes or just one independent gearbox and drive depending upon the engineering drawings, which form a gear-train and produces the required rpm and torque generated by the cumulative flywheels discharging energy into the shaft of the 1500 KW generator by the rotating flywheels. The design cycle is, after 10 seconds of input power all the motors will be switched off except one standby 700 kw motor is switched on connected to the very first wheel there by it is helpful to rotate the complete wheel chain in between 3000 to 6000 rotations by doing this the sudden bursting pressure of high angular acceleration coming from the shaft to the rim i.e. surface velocity generated will maintain the rpm for a long time there by the 700 kw motor will help keep the 5 independent flywheels connected with each other in constant rotations for more than 3600 seconds. The intriguing thing about this system is that greater electrical output power can be obtained from the output of the generator than appears to be drawn from the input motor. This is done with the help of Gravity wheel. The gravity wheel or flywheel is coupled with the gear-train in order to produce more excess energy or free energy. Flywheel power multiplication technology is the generation of clean electricity and is characterized by large extents of nil or no fluctuations in power quality and frequency stability. High rpm's generate maximum torque there by the flywheels will rotate for longer periods of time, decelerates and once again turbocharged, the kinetic energy recovery, back to back system and generate more energy than the Input consumed power by the motor. For example if we use High rpm flywheel and low rpm generator will make more electricity than the Input electricity consumed by the motor to rotate the series of flywheels fixed in a cascade because of the cumulative flywheel torque multiplications.

Please calculate the torque of 67000 kg torus ring flywheel with minimum 3 meters and maximum 4.5 meters in diameter and minimum 6000 and maximum 7000 rpm within 10 seconds and calculate the torque of the 1000 kg weight of 1500 KW generator rotor diameter of 441 mm with 1000 rpm and 0.15 m³ total cylinder area, there by the calculations prove that free energy is generated using math's and physics. The 67000 Kg with 3 diameters chain of 5 flywheels connected with each other will not stop immediately as it is getting rotated from 6000 to 7000 rpm within 10 seconds time. As soon as the 5 independent 3000 kw motors (one motor for each wheel) are switched off the 67000 Kg weight flywheel will rotate loosing maximum 500 rpm in a non linear motion for every one hour, there by more than 3600 seconds is the free electricity generated. The 67000 kg weight flywheel is coupled with a speed increasing gear box and rotated from 6000 to 7000 rpm then a



*speed decreasing gearbox to rotate the low rpm generator at 1000 rpm or less. Because of high angular acceleration the flywheel will not stop immediately because of Gravity-Powered Systems fixed and rotated in vacuum chamber and by confirming the extra energy by rotating the flywheel rapidly and then transferring the sudden bursting torque into the shaft of the generator connected to the flywheels within 10 seconds, this result is a self-powered system capable of running extra loads.*

*Introduction to Flywheel Energy Storage also known as FES, are used in many technical fields. Higher inertial mass will help achieve very high revolving speed and maintaining the energy in the system as rotational energy for a long time. The energy is transformed back by slowing down the last flywheel gearbox output shaft rpm to suit the low rpm generator's shaft rpm. The available performance comes from Inertia effect and rotational speed. Flywheel mass is either mechanically driven by CVT gear unit or electrically driven via electric motor / generator unit, mechanically driven composite flywheel, electrically driven flywheel Devices that use mechanical energy directly are being developed, but most FES systems use electricity to accelerate and decelerate the flywheel for power generation.*

**Keywords:** Flywheel, Power Multiplication, Conventional Energy, Free Energy, Gravity Power System, Generator, vacuum, green power, Batteries, ring gear.

## 1. INTRODUCTION

This paper presents the design, construction, and test of a high-speed integrated multiple flywheel energy storage cum generating system arranged in cascade or series or parallel. In house experiments were conducted in my workshop for speeds up to 2000 rpm and power levels up to 160 kW using custom made gears and making flywheel as ring gear with small pinion gear rotating inside the ring gear to connect the generator, we have achieved super speeds of the rotor in seconds. System efficiencies of 83%, which includes losses in the power electronics and the motor, were achieved. Most experimental results were in line with designed values. Experimental measurements of the harmonic losses showed very good agreement with the analytical calculations, and demonstrated that low rotor losses have been achieved. Flywheels have higher power densities, higher efficiency, longer lifetime and a wider operating temperature range. Kinetic energy can be described as "energy of motion," in this case the motion of a spinning mass, called a flywheel. In our innovation we are using Flywheels for electrical generation because the flywheel rpm is having Inertia and angular acceleration as the base for storing energy in max 10 seconds and discharging in more than 3600 seconds, with sudden rapid burst of rotations and release the stored energy suddenly to counter affect the reverse torque coming from the generator when load is applied and generate pure green electricity for many running hours continuously.

Stored energy is proportional to the flywheel's mass and the square of its rotational speed, here please remember we are using 15000 kw motor power for max 10 seconds only and rotate 67000 kg to 6000 or 7000 rpm. Advances in power electronics, magnetic bearings, and flywheel materials coupled with innovative integration of components have resulted in AC current directly to use.

- what is the resistance force developed when full load is applied.

- Electromagnetic torque and electromagnetic force  
When the machine runs steadily at a constant rpm then  $T_e = T_{load}$  and  $T_e = T_{pm}$ ,
- It may be noted that the direction of conductor currents reverses as we move from one pole to the other
- the lines of forces are concentrated near the trailing edge thereby producing torque in the opposite direction of rotation.
- In our experiments observations, Reverse torque is 65 kg/inch³ for 1500 kw power generation.
- For the 1500kW 1500RPM 3phase 50Hz Generator
- $T_o = 143 \text{ N.M}$  (Start torque per cubic inch of the rotor area)
- $T_e = 9550 \text{ N.M}$  (Electromagnetic torque per cubic inch of the rotor area)

The flywheel diameter is 3000 mm or 3 meters so how many centimeters are there in 3 meter 23562 or 9276.37 inches and this is the pressure area exerted on the 3 meter dia flywheel @ 65 kg per cubic inch. The wheel is round in shape, the wheel in the middle is harrow and rim is Torus ring design. The maximum weight is on the top of the Rim of harrow

i.e. for example if the Harrow weight is 3000 kg and the torus is 10000 kg here the width or maximum thickness on the rim is very important to generate high surface velocity.

When load is applied why Flywheel rpm will fall down suddenly or come down is the prime question within the flywheel power generation sector and this question has to be answered considering the reverse or back or negative torque lashed out by the generator. When load is applied on the generator the flywheel rpm will reduce suddenly to max 600 to 700 rpm in just a second i.e. max 1 to 2 seconds time and this is the sudden reverse or back torque generated by the applied load on the generator. There by the motor will

have the maximum stress and will not be in a position to rotate the 67000 kg flywheel back to normal rotations which were there in the very beginning time when there was zero or no load and the flywheels are rotating freely coupled with the 1500 kw generator and rotated on the Plummer block bearings. This reverse torque is the biggest hurdle for power generation. How to neutralize it is the ultimate question asked by everyone and for doing this we have taken 67000 kg weight as the weight of the flywheel, 3 meters as the diameter and rotated to 6000 rpm to generate the counter torque to neutralize the reverse torque in max 10 seconds time. We can take the flywheel to much more sudden bursts of rotations if required for power multiplication as of now we are going up to in between 6000 to 7000 rpm.

In one meter, Centimeters are 7853.98 and for 3 diameter circle it will be 23562 centimeters and in 3 diameter circle the Psi pressure is 8238600 or 57566290000 Nm acting as reverse torque coming from the 0.15 m³ diameter of the cylinder shape rotor and effecting the Rotations of the flywheel in fraction of second's time 57566290000 Nm is the reverse torque is generated from the Rotor of 1500 kw generator and 68219893094 Nm generated from the 67000 kg flywheel with 3 diameter, here please note the difference in both the torques and rpm's. Total motor's used are 5 numbers of 3000 kw each and working time 10 seconds time, consume 11 amps per motor there by 55 amps consumed and 1 motors of 700 kw running for 3600 seconds time, to rotate 67000 kg weight flywheel in between, from 3000 to 6000 rpm consume 585 amps. 4.5 Kg weight is for 1 KW power used by using 15000 kw motor.

For nonstop power generation always there will be 2 independent sets and each independent set will work for 6 hours max at a stretch and 6 hours rest.

The amps consumed by the 15000 kw motor are 585 amps in 10 seconds and the generator generated amps are 2318.67 for 3600 seconds this proves the flywheel power multiplication is successful.



### ***The concept:***

How we have arrived to formulate this formula for generation of the power using flywheel is,

### ***Concept Idea:-***

Using Hydro power formula for flywheel power generation:-

Head X Flow X Gravity X Efficiency = KW

h- 3 m X f – 67m³/sec X g – 9.81 X eff- 92%= 1500 KW  
power generated per hour.

Now in Flywheel technology: our formula is

Head X Flow X Gravity X Efficiency = KW is adopted and made like this. Head converted to the total Diameter i.e. 3 meters round in shape torus ring wheel X Flow is the water weight liters changed to kg of the Flywheel i.e. 67000 Kilograms or 67 tons carbon steel torus ring wheel X Gravity is 9.81 X Efficiency of 92% in combination of { Torus flywheel + Generator + Transformer } 92% = KW generated. Please take the Torque value of the Torus ring wheel with 67000 Kilograms weight and 6000 rpm in 10 seconds and 3 meters in Diameter round wheel where the maximum weight is on the periphery of the wheel or on the top side of the Rim of the wheel with small r as the maximum width and thickness of the wheel. Convert the Torque of the rotating wheel in 10 seconds time and you get Nm again convert into joules and then into Kwh. Here the Speed (RPM), diameter, weight, time are the deciding key factors for generating the torque from the torus wheel to counter the reverse torque from the generator of 1.5 MW generator with 1500 rpm, 65 kg pressure as reverse torque is must coming for 1.5 MW generator to counter act the Air Gap Torque, Shaft back Torque when we keep the full load, reverse torque decreases volts, Hz and rpm, To counter all this the Flywheel should have maximum torque then only we can generate grid connectivity power with 50 or 60 HZ and required voltage. We are using Math's and Physics to do our calculations.

Power (kW) = Torque (Nm) x Speed (RPM) / 9.5488

Nm of the 3000 KW HT motor with 3000 rpm

Please understand the torque of the 5 motors i.e. 9548.80 Nm per motor x 5 = 47744.00Nm

2nd motor

2228.05 Nm of the 700 KW HT motor with 3000 rpm

Now coming to the using of this 15000 kw motors 47744.00 Nm torque to rotate 67 tons of weight with 3 m dia flywheel to 6000 rpm

5 flywheel cumulative rpm is 30000 rpm ( each flywheel rpm 6000 x 5 nos) and the negative torque coming from the 1.5 MW rotor 1000 rpm will be neutralized, with no drop in the flywheel rpm.

## 2. CONCLUSION

This paper presents a critical review of FESS in regards to its main components and applications, an approach not captured in earlier reviews

Each individual 13 ton with 3 diameter steel flywheel must be designed for hard wearing and resistant to cracking for very high speed rotations.

A high carbon steel, tensile strength of 1200 N mm⁻² and hardness of high carbon steel is about 390 HB.

Steel will be made up of ferrite and cementite. The microstructure of steel, however, will consist fully of pearlite. Carbon, up to a maximum of 0.82%, and manganese, to a maximum of 1.7%, are needed to produce hard, wear resisting.

Single flanged wheels, Heavy duty alloy steel flywheels provide optimal strength and durability for transferring heavy loads safely and efficiently, Using cast and forged steel wheels for heavy duty ensures minimal need for replacement.

An alloy configuration, particularly adapted for the manufacture of heavy duty flywheels, and having an improved combination of hardness, and thus wear resistance, plus resistance to thermal cracking in flywheel applications; the alloy consists essentially of in weight percent, carbon 0.48 to 0.64, phosphorus 0.05 max., sulfur 0.05 max., manganese 0.60 to 1.10, chromium 0.30 to 0.60, nickel 0.50 max., and balance iron.

**Always calculate these parameters to know the total strength of flywheel**

Fly Wheel Mass (Kg.)

Radius of Torus (inch) major R width

Radius of the Rim (Inch) minor r maximum thickness

Initial RPM

Final RPM

Time (Seconds)

Moment of Inertia (Kg.m²)

Angular Velocity

Angular Acceleration

Torque Acquired (N.m)

Kinetic Energy of Fly Wheel (J)

Centripetal Acceleration (m/s²)

Centripetal Force (N) [ $m v^2/r$ ]

Surface Velocity † m/s to the center and to the periphery

Linear speed:

Centrifugal acceleration:

Centrifugal force

## Tangential velocity

Aligning the natural axis of the wheel's rotation with the desired rotation of the generator and using Compact and durable motors design will operate at high speeds without getting overheated will always increase the energy efficiency of flywheel rpm. So the maximum amount of energy stored doesn't depend directly on inertia or on the angular velocity, since either of these can be chosen independently to obtain the required design stress. And within the design stress, the amount of energy stored is linearly proportional to the moment of inertia and to the square of its angular velocity. This technology will have multi-task to serve provision of capacity, load, peak shifting, frequency regulation, frequency response, and more, all within a single installation. Multiple numbers of One  $\frac{3}{4}$  horsepower (hp) vacuum pumps are used continuously to achieve a vacuum between 10 and 50 milliTorrs (mTorr) on continuous duty for 6 hours and for the bearing system uses a hybrid mechanical and magnetic bearing arrangement, that results in long life, low drag, and fail-safe functionality. Combination of mechanical bearing drag, wind-age and electromagnetic drag torques, is very challenging to dis-aggregate these losses from each other, as they occur simultaneously, the main components of spinning loss should be understood in power generation.

The total flywheel are 5 in number, each independent flywheel is 13 to 15 tons there by if one is connected to another by flanges and untidily rotated.

If the first flywheel is rotated to 7000 rotations in 10 seconds time then the entire 5 flywheels cumulative rps ( rotations in 10 seconds ) will be 35000 rotations.

If the generator we choose is 750 rpm then we have to divide the generator rpm with 60 seconds then we will get the 10 seconds rotations 125 rotations in 10 seconds.

The first wheel is drive and the 4 other wheels are driven so all 5 independent flywheels are rotated at the same time so the cumulative rpm is the deciding factor of the torque coming from the cumulative rotations of the 5 flywheels which are a combined force to rotate the generator coupled to the 5 flywheels there by the torque coming from the rotation of the 5 flywheels is always more than the independent generator.

So when we are stopping the input current to the motor then the rps of the 5 independent flywheels will slowly come down to 3000 rotations in a non linear method and it will take more than 1 hour to come down. 35000 rotations is the total cumulative torque in 10 seconds

Generator rpm 125 rotations in 10 seconds there by the flywheel power multiplication

system has longer continuous discharge time and saves energy which makes the flywheel from a standstill to the lowest effective speed.

According to the rotations, we can see that when the flywheel gets its lowest effective speed, its energy left is still about 1/4 of the energy contained by the flywheel in its highest speed. It is not difficult to find when the flywheel is reduced to the lowest effective speed, the energy left is equivalent to 1/3 of the maximum energy stored by the flywheel. From this it can be seen, if the energy left can be retained in flywheel with lowest effective speed, this will save a sizable portion of energy at the time of once again charging for the flywheel. Due to the development of vacuum technology and superconducting maglev technology, the wind loss and bearing loss have become very little. And only a small amount of electricity is required to maintain the operation status of the flywheel

### *Some useful formulas*

The amount of energy 'E' stored in a flywheel varies linearly with moment of inertia 'I' and with the square of the angular velocity 'ω'.

$$E = \frac{1}{2} \cdot I \cdot \omega^2$$

Physical quantity of inertia, is the integral of the square of the distance 'x' from the axis of rotation to the differential mass 'dmx'

$$I = \int x^2 dm_x$$

Cylindrical flywheel of mass 'm' and radius 'r'

$$I = m \cdot r^2$$

Energy stored is proportional to the square of angular velocity

$$E = \frac{1}{2} \cdot m \cdot r^2 \cdot \omega^2$$

Energy stored can be expressed in terms of peripheral velocity 'v',

Perpendicular distance from the axis of rotation and angular speed as

$$E = \frac{1}{2} m \cdot v^2 \quad \text{since} \quad v = r \cdot \omega$$

For a mass density 'ρ', the tensile strength

$$\sigma = \rho \cdot v^2$$

Energy density, Em, is loosely defined for a flywheel as the ratio of energy stored to its mass

$$E_{vmax} = \frac{1}{2} \cdot \sigma_{max}$$

Stored energy equation, as the product of volume and the mass density

$$E_{mmax} = \frac{1}{2} \cdot \frac{\sigma_{max}}{\rho}$$

General expression of maximum energy stored per mass, K is flywheel shape factor

$$E_{mmax} = K \cdot \frac{\sigma_{max}}{\rho}$$

Energy stored per mass, where 's' is the ratio of minimum to maximum operating speed, usually set at 0.2

$$E_m = (1 - s^2) \cdot K \cdot \frac{\sigma}{\rho}$$

The paper concludes with recommendations for future research.

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# R&D and Market Analysis for Product Development Process in Achieving New Product Development Success

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**Abstract:** Globalization challenges the companies to exploit their creativity for sustaining in the strong competitive market environment. Innovation ensures industrial sustainability through proper utilization of the available resources. Continuous research and development (R&D) shapes the new ideas and develop innovative products by analyzing the market through identifying customers demand. This empirical study portrays the role of R&D and market analysis to enrich the product development process (PDP) for new product development (NPD) success. The primary data from 76 experts from Indian manufacturing industries have been collected for data analysis purpose. Structural equation modeling (SEM) approach has been used to develop the path model using IBM SPSS AMOS 21.0 software packages depicting the positive impact of R&D and market analysis on product development process (PDP) for successful new product development which is turn be quantified by quality measures such as meet quality guidelines, achieved product performance goal and achievement of design goal.

**Keywords:** Critical success factors, product development performance, structural equation modeling (SEM)

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## 1. INTRODUCTION

Customer satisfaction is the crucial aim of the company to achieve success in the volatile market environment. Globalization results in unpredictable customer desires according to the updated needs among the end-users. This leads towards application of innovative ideas for new product development (NPD) (Buyukozkan and Arsenyan, 2012). There are several constituents closely associated with success and survival of the company by controlling NPD activities. These factors are famously renowned as critical success factors (CSFs) (Ernst, 2002; Bhuiyan, 2011). Among various factors technology (Lau, 2011; Mendes and Ganga, 2013; Yeh, Pai and Liao, 2014), managerial support (Sun and Wing, 2005; Cooper and Kleinschmidt, 2007; Felekoglu and Moultrie, 2014), cross-functional teamwork (Ernst, Hoyer and Rübsaamen, 2010; Thamhain, 2011; Fazilah, Jaafar and Suraya, 2014) are the commonly discussed by previous researchers. Research and development (R&D) is another essential activities every firm for successfully develop new products with best qualities as per customers' requirements. Previous literatures (Cooper and Kleinschmidt, 2007; Ernst, Hoyer and Rübsaamen, 2010; Wang and Lestari, 2013; Yeh, Pai and Liao, 2014) identifies the need of R&D in large industries as well as in small and medium enterprises (SMEs) also. In practical scenario there are a lack of investment is R&D in SMEs which driving them in backward direction in the global competition (Sun and Wing, 2005). R&D requires a clear idea about the market condition and requirements of targeted customers. This

leads towards the continuous market analysis. Researchers (Sadeghi, Azar and Rad, 2012; Medeiros, Ribeiro and Cortimiglia, 2013) signifies the role of identification of target market for developing successful new products. These NPD activities need a systematic product development process (PDP) which has been neglected in the SMEs due to the higher cost involved in association with the uncertainties of the market acceptance (March-Chorda, Gunasekaran and Lloria-Aramburo, 2002). Previous researches (Spivey, Munson and Wolcott, 1997; Lewis, 2001; Tzokasa, Hultink and Hart, 2004) have portrayed the need of PDP for achieving NPD success. Like success factors there are success measures which are used to quantify the NPD success. There are time based measures (Lynn, 2005; Sivasubramaniam, Liebowitz and Lackman, 2012), cost based measures (Cooper and Kleinschmidt, 2007), customer based measures (Huang, Soutar and Brown, 2004) for measuring the ultimate NPD success according to their requirements. Therefore, the clear identification of the factors impel product development success is essential to be recognized to optimal utilization of the available resources for PDP to increase the market demand for new products developed in firms. R&D and market analysis controls the PDP for developing new products as per customer demand. The main objective of this study is to realize the role of R&D and market analysis to control PDP which escalates NPD success again be quantified by quality based measures such as meet quality guidelines, achieved product performance and achievement of design goals. This empirical research



collects the primary data from 76 design and development experts of Indian manufacturing industries for developing the framework depicting the impact of R&D and market analysis on PDP for NPD success. Various reliability indices like composite reliability (CR), average variance extracted (AVE) and Cronbach's Alpha reliability has been conducted to test the reliability of the empirical data set. Structural equation modeling (SEM) approach has been used to develop the interrelationship of the factors for realizing the effects of the aforesaid factors on quality of the developed new products essential for NPD success.

## 2. METHODOLOGY

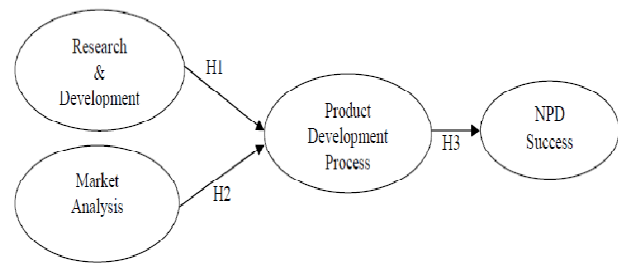
Structural equation modelling (SEM) approach is used here to structure a model depicting the interrelationship of factors, estimating the path values and finally the testing of the developed model through various model fitness tests (Rigdon, 1998). In this study, SEM is used to portray the impact of R&D and market analysis factors on PDP and correlate them with the NPD success which in turn be quantified by quality based measures. This comprehensive statistical approach tests the hypotheses developed among the constructs and depicts the effectiveness of manifest variables to measure the latent constructs as well (Hoyle, 1995). This research develops a structural model clearly depicts the role of R&D to lead the PDP towards correct direction for better NPD and market analysis also supports the PDP activities for the same purpose as R&D. For the effect of these two constituents PDP gets a positive direction escalating the NPD success for developing quality products for customer satisfaction. Valuable responses from 76 design and development experts from Indian manufacturing industries have been collected and analyzed for developing the structural model. CR, AVE and Cronbach's Alpha ( $\alpha$ ) have been calculated by using IBM SPSS 21.0 software for testing the reliability of the collected data for future analysis. SEM approach is used for developing the path model showing the interrelationships of the factors by using IBM SPSS AMOS 21.0 software packages.

This study involves the formulation of three hypotheses which have been tested are enlisted below. The path model showing the interrelationships of the constructs are shown in Fig. 1.

H1: Research and development (R&D) positively influences product development process (PDP).

H2: Market analysis (MA) has a positive impact on product development process (PDP).

H3: Product development process (PDP) escalates new product development success (NPD Success).



**Fig. 1. Path model of constructs depicting the assumed hypotheses**

## 3. RESULTS

### 3.1 Analysis of Measurement Validity

Primary data collection has been conducted from Indian manufacturing industries to accomplish the research objectives. The sectors and number of respondents participating in the survey is been enlisted in Table I. The realization of the role of R&D and market analysis on PDP to escalate NPD success involves segmentation of the manifest variables into two section, such as importance and implementation. This approach adds an extra novelty to this research. All item measures are based on 7 point likert type scale where 1 denotes strongly disagree and 7 denotes strongly agree for importance whereas, 1 denotes very low and 7 denotes very high for implementation and success measures. the reliability of the survey data has been performed by calculating CR, AVE and Cronbach's Alpha values by IBM SPSS 21.0 software. The CR values above 0.5 are considered as highly reliable, whereas, CR values in between 0.3 to 0.5 are also moderately reliable. Again in case of Ave, values greater than 0.5 is trustworthy for analysis.  $\alpha$  values greater than 0.8 is highly reliable for data analysis though values near 0.7 can also be acceptable (Ong, Lai and Wang, 2004). The standardized regression weights (SRWs) of manifests have been calculated and listed in Table II including the values of reliability indices.

**TABLE 1: Sectors and number of respondents participating in the empirical study**

Manufacturing Sectors	Respondents
Fabrication	13
Electrical Equipments	10
Industrial Valves	10
Textile Machineries	9
Fire Fighting Equipment	9
Hydraulics & Pneumatic	6
Burner and Heaters	6
Material Handling Equipment	6
Cell and Battery	3
R&D Sectors	2
Air Ventilators	2
Total Number of Respondents	<b>76</b>

### 3.2 Measurement Model Results

Confirmatory factor analysis is applied for estimation of the model fitness. The estimation of path values is a vital part of the analysis as it describes the relationships between the variables which portray the model fitness. Besides, evaluation of model fitness can also be performed by using multiple methods such as chi-square including degree of freedom (Hu and Bentler, 1998), goodness-of-fit (GFI), adjusted-goodness-of-fit (AGFI) and root mean square of error approximation (RMSEA) (Bentler, 1990; Chen, 2015).

The results of the fitness tests show that the model fitting values are within the desired range as  $\chi^2 = 412.03$ , degrees of freedom = 242,  $\chi^2$  /degrees of freedom = 1.703, RMSEA = 0.047, GFI = 0.829, AGFI = 0.805 (Hair et al., 2010). The SRWs which depicts the path values are within the range of 0.42 to 0.98 as listed in table II that is greater than 0.4 that means all the paths can be considered as feasible. The values of reliability indices such as CR is within the range of 0.59 to 0.68, AVE is from 0.47 to 0.54 and  $\alpha$  is from 0.797 to 0.822 depict the reliability of collected data as shown in table II.

### 3.3 Structural Model Results

After development of the measurement model the next step is the formation of structural model for calculating the model-to-data fitness by performing the fitness tests same as like measurement model analysis. In this case also, the values of the fitness parameters are within the accepted range as  $\chi^2 = 443.009$ , degrees of freedom = 264,  $\chi^2$  /degrees of freedom = 1.678, RMSEA = 0.043, GFI = 0.904, AGFI = 0.886 (Hair et al. [12]). The structural model defines the relationships of the R&D and market analysis constructs to control the PDP for NPD success. IBM SPSS AMOS 21.0 software package has been used to realize the relationship of the constructs by developing the framework using SEM approach. The value of path estimates between R&D and PDP is 0.70 and between market analysis and PDP is 0.57. These values depict the influential role of R&D and market analysis to positively motivate the PDP for better NPD. Again, the path value between PDP and NPD success is 0.95 which interprets that PDP has a high positive impact on NPD success which in turn be quantified by quality based measures of the developed product. These estimates are enlisted in table III and the structural model portraying the interrelationships is shown in Fig. 2.

**TABLE 2: Constructs and their Indicators including Reliability Indices**

Latent Variables and their Manifests including Reliability Indices	SRWs
1. Research and Development (R&D) [CR=0.68, AVE=0.54, $\alpha$ =0.822]	
a) Investment in R&D infrastructure (RndD1)	0.95
b) Number of R&D persons (RndD2)	0.42
c) Experience of the R&D team members (RndD3)	0.89
d) Qualification of the R&D team members which affects the continuous flow of the product development (RndD4)	0.61
e) R&D management vision and direction (RndD5)	0.81
f) Number of patents (RndD6)	0.95
g) R&D oriented culture (RndD7)	0.75
h) Investment of methods for sustainable development (RndD8)	0.49
i) Scope and facility (RndD9)	0.71
2. Market Analysis (MA) [CR=0.59, AVE=0.47, $\alpha$ =0.797]	
a) Generation of well-established market plan (MA1)	0.51
b) Degree of Market growth (MA2)	0.43
c) Emphasis on customer satisfaction (MA3)	0.86
d) Knowledge about consumption pattern (MA4)	0.49
e) Need for identification of target market (MA5)	0.98
f) Market testing (MA6)	0.76
g) Advertising and promotional activities (MA7)	0.59
h) Effort in competitor monitoring (MA8)	0.91
3. Product Development Process (PDP) [CR=0.62, AVE=0.50, $\alpha$ =0.808]	
a) Investment in PDP (PDP1)	0.80
b) Application of updated technological innovations in NPD (PDP2)	0.66
c) Adequate number of new products introduced to market (PDP3)	0.46
d) Involvement of customers in NPD (PDP4)	0.91



e) Involvement of marketing, market research in PDP (PDP5)	0.72
f) Training provided on NPD Management (PDP6)	0.47
g) Concurrent workflow of product development activities (PDP7)	0.55
h) Hands-on-working-experience of people involved in PDP (PDP8)	0.72
i) Active use of in house knowledge database in development process (PDP9)	0.86
j) Early involvement of manufacturing department in NPD (PDP10)	0.94
k) Usage of Failure Mode Effect Analysis (FMEA) (PDP11)	0.56
l) Design for manufacturability (DFM) (PDP12)	0.73
m) Practice of Lean Manufacturing (PDP13)	0.63
n) Adoption of Just-in-Time (JIT) culture (PDP14)	0.68
4. NPD Success (NPD Success)	
[CR=0.65, AVE=0.51, $\alpha$ =0.810]	
a) Meet quality guidelines (Q1)	0.71
b) Achieved product performance goal (Q2)	0.92
c) Achievement of design goal (Q3)	0.67

TABLE III: Statistics of path estimates

Path Description	Hypothesis	Estimate
R&D $\rightarrow$ PDP	H1	0.70
MA $\rightarrow$ PDP	H2	0.57
PDP $\rightarrow$ NPD Success	H3	0.95

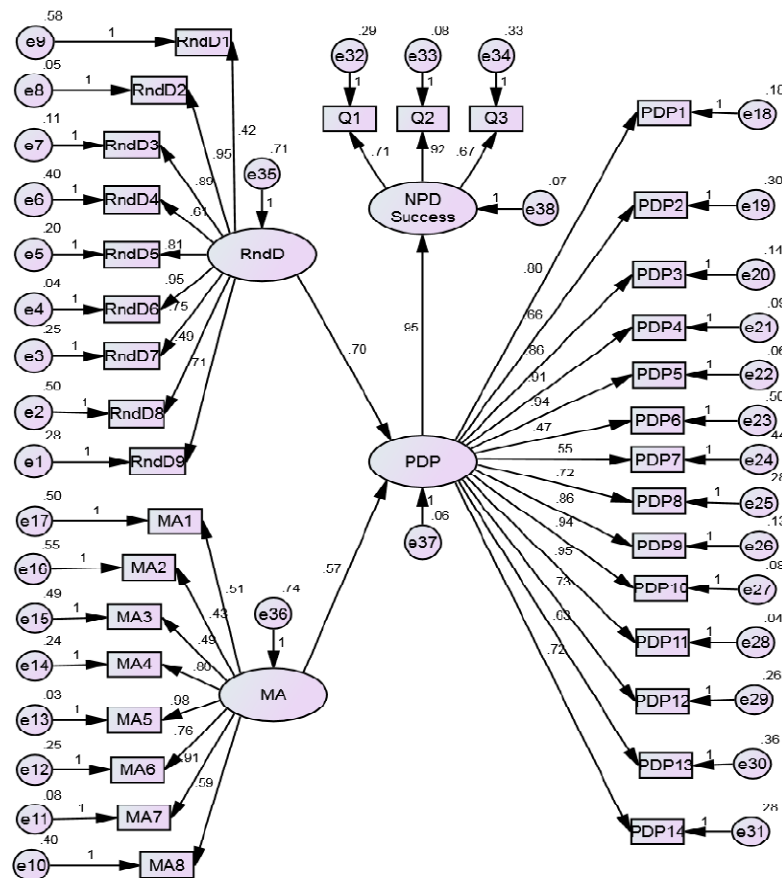


Fig. 2. Structural Equation Modeling (SEM) model of interrelationships of constructs and their manifests after execution

#### 4. DISCUSSION AND CONCLUSION

This empirical study explores the vitality of PDP for NPD success in Indian manufacturing industries. NPD becomes an inevitable part for sustaining in the challenge of the global competition. In this research, role of PDP to escalate the NPD success have been established. Adequate investments in PDP and introduction of various activities during NPD process such as DFM, FMEA, JIT, lean manufacturing enhances the PDP for achieving NPD success. Again, PDP is positively influenced by R&D and market analysis. R&D includes the innovation of creative ideas and shapes them for successful product development. Investments in R&D activities along with qualified and experienced R&D experts with proper R&D vision and direction helps to achieve a strong R&D practice in the firm which enhances PDP activities as well. Similarly, the market analysis is equally important for NPD success as because product development without identification of the market requirement is a completely infeasible phenomenon for successful NPD. Proper market analysis includes a well-established market plan for providing customer satisfaction along with knowledge of consumption pattern, degree of market growth, identification of target market, systematic market testing, competitor monitoring and finally conducting advertisement and promotional activities. The developed structural model defines the essentially of R&D activities and market analysis for successful completion of PDP for NPD success which in turn is quantified by quality based measures of newly developed products.

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# Effect of Roller Burnishing on Surface Roughness and Micro Hardness of AA6082 Alloy using Box-Behnken Design of Experiment

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**Abstract:** Conventional machining process leaves surface irregularities, which causes additional cost of finishing operations. Surface finish is required to avoid friction losses, good corrosion resistant property and high fatigue life. Roller burnishing operation is a finishing process in which hardened tool is rolled round metallic surface. In this paper, an experimental study is carried out to investigate the effect of machining parameters such as speed, feed and number of tool passes on surface roughness and micro hardness of AA6082 alloys by evaluating the effect of individual parameters and their interaction on response parameters using lathe machine. The experiment is conducted on a Mysore Kirloskar Lathe machine and the experiments are designed using Box-Behnken method of Response surface methodology. Surface roughness and micro-hardness are measured using Mitutoyo surface measurement machine and micro hardness tester respectively and the results are plotted graphically.

**Keywords:** Burnishing of AA 6082, Surface finish, Micro hardness, Design of Experiment, Box-Behnken

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## 1. INTRODUCTION

Wear has great technological and economical significance as it alters the shape of the work piece and tool and the tool-workpiece interface (Hasan, Sulieman and Dhifi 1999). Surface roughness and hardness plays an important role in the functioning of machined parts (Thamizhmanai, Omar, Saparudin and Hassan, 2008). Roller burnishing is a cold worked, chip less process used to improve surface characteristics (Thamizhmanai, Omar, Saparudin and Hassan, 2007). The burnishing process is done by applying pressure on to a metallic surface using hard and polished roll causing the peaks on the metallic surface to get smoothed out permanently when the burnishing pressure increases the yield strength (Hasan, 1997). The metallic surface smoothed and becomes work hardened because of plastic deformation. The material is left with residual stress distribution, that is compressive on the surface (Wick, Veilleux 1985).

Burnishing process improves quality of surface, microhardness, residual compressive stress, good surface roughness, wear resistance, improved tensile and fatigue strength and better roundness on the workpiece surface (Axir, Ibrahim 1998; Axir 2000; Lee, Tam, Loh 1993; Khabeery, Axir 2001; Hassan, Bsharat 1996; Lee, Tam, Loh 1992; Hassan 1997). Surface finish depends on various parameters which are burnishing force, feed, ball or roller material, number of passes, workpiece material, lubrication

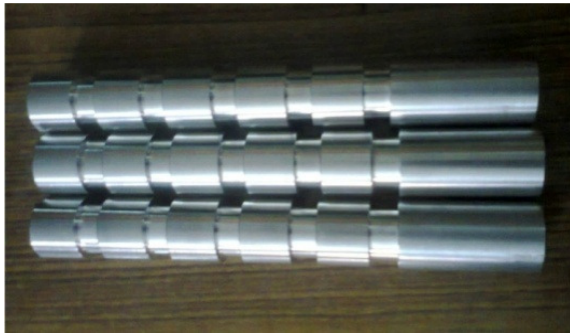
and machine and tool stability (Axir, Ibrahim, 2005). Selection of optimal machining parameters are important to ensure quality of machined products and reduced machining cost (Milfelner, Kopac, Cus, Zuperl, 2006). In burnishing, heat generated due rubbing between roller/ball and workpiece process overheats the workpiece and tool (Rubio, Camacho, Sola, Marcos, 2006).

It is imperative to look for new tool designs and optimal combinations of cutting parameters to optimize the machining parameters (Dolinsek, Kopac, 2006).

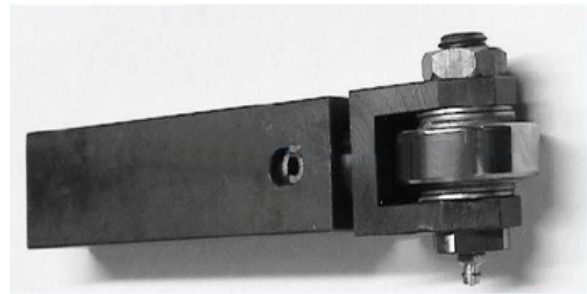
## 2. TOOLS AND EQUIPMENT

### 2.1 AA6082 specimen and Burnishing Tool

The round stepped specimen of AA6082 alloy is shown in Fig. 1 and chemical composition and mechanical properties is shown in table 1. The Roller burnishing tools are made up of Hardened Steel. A complete burnishing tool consists of the basic tool and the burnishing head. The basic tool is designed for a wider range of applications within which the burnishing heads of different design may be exchanged. Each burnishing head consists of a cage, tape sand rollers. These parts may also be replaced in case of wear. The burnishing tool used for this study is shown in Fig. 2 and the composition and mechanical properties of the same is shown in table II.



**Fig 1. AA6082 round stepped specimen**



**Fig 2. Burnishing tool**

**TABLE 1: Composition and mechanical properties of AA 6082**

Element	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
Composition (%)	0.446	0.256	0.008	0.012	0.447	0.034	0.015	0.027	Balance
	Yield Strength		Tensile strength						
	214 MPa		241 MPa						

**TABLE 2: Composition and mechanical properties of burnishing tool**

Element	C	Si	Mn	Ni	Cr	Mo
Composition (%)	0.2	0.35	0.70	0.55	0.45	0.25
	Yield Strength		Tensile strength			
	695 MPa		930 MPa			

## 2.2 Burnishing operation set up in Mysore Kirloskar lathe

The roller burnishing operations are done on the Mysore Kirloskar Lathe machine with 4 jaw chuck. The technical specification of the lathe is shown in table III.

**TABLE 3: Technical Specification of Mysore Kirloskar lathe**

Maximum Swing over bed	380mm
Maximum Swing over carriage	200mm
Maximum Swing in gap	610mm
Length of bed	2235mm
Number of spindle speeds	12

Standar speed range	32-1500 rpm
Number of feeds	36

## 3. DESIGN OF EXPERIMENT

The Box-Behnken design is a response surface methodology (RSM) design that requires only three levels to run an experiment. It is a special 3-level design because it does not contain any points at the vertices of the experiment region. This could be advantageous when the points on the corners of the cube represent level combinations that are prohibitively expensive or impossible to test because of physical process constraint. The process parameters and their levels are shown in table IV.

**TABLE 4: Process parameters and their levels**

Process parameters	Units	Levels		
		Level (-1)	Level (0)	Level (+1)
Speed	Rpm	135	190	270
Feed	mm/rev	0.22	0.42	0.65
Number of tool passes		1	2	3

A series of burnishing process were conducted on a centre lathe to investigate the influence of the process parameters like feed, speed and number of passes on the surface finish and micro hardness. The plan of experiments are tabulated and is shown in table V.

**TABLE 5: Plan of experiments**

Std. order	Run order	Coded Factors			Actual Factors		
		Speed (rpm)	Feed (mm/rev)	Number of tool passes	Speed (rpm)	Feed (mm/rev)	Number of tool passes
10	1	0	1	-1	190	0.65	1
15	2	0	0	0	190	0.42	2
5	3	-1	0	-1	135	0.42	1
6	4	1	0	-1	270	0.42	1
8	5	1	0	1	270	0.42	3
1	6	-1	-1	0	135	0.22	2
12	7	0	1	1	190	0.65	3
4	8	1	1	0	270	0.65	2
2	9	1	-1	0	270	0.22	2
13	10	0	0	0	190	0.42	2
11	11	0	-1	1	190	0.22	3
3	12	-1	1	0	135	0.65	2
9	13	0	-1	-1	190	0.22	1
14	14	0	0	0	190	0.42	2
7	15	-1	0	1	135	0.42	3

#### 4. SUMMARY OF RESPONSES

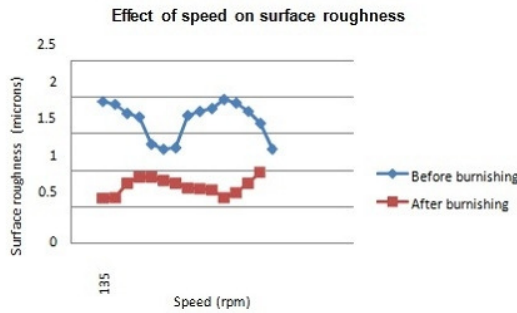
The responses are recorded after taking the readings from Mitutoyo surface roughness measuring machine for surface roughness in  $\mu\text{m}$  and H-V 1000 series micro hardness tester for micro hardness in VH. The responses are tabulated and is shown in table VI.

**TABLE 6: Summary of the responses**

Std order	Run order	Speed (rpm)	Feed (mm/rev)	Number of passes	SR before burnishing ( $\mu\text{m}$ )	SR after burnishing ( $\mu\text{m}$ )	Micro hardness before burnishing	Micro hardness After Burnishing
10	1	190	0.65	1	1.94	0.82	133.3	140.8
15	2	190	0.42	2	1.99	0.80	125.8	142.8
5	3	135	0.42	1	1.92	0.90	129.6	136.2
6	4	270	0.42	1	1.86	0.82	131.3	140.2
8	5	270	0.42	3	1.83	0.62	119.4	154.0
1	6	135	0.22	2	1.25	0.72	106.2	132.5
12	7	190	0.65	3	1.28	0.60	131.2	139.5
4	8	270	0.65	2	1.30	0.65	120.5	128.2
2	9	270	0.22	2	1.28	0.68	199.6	128.4

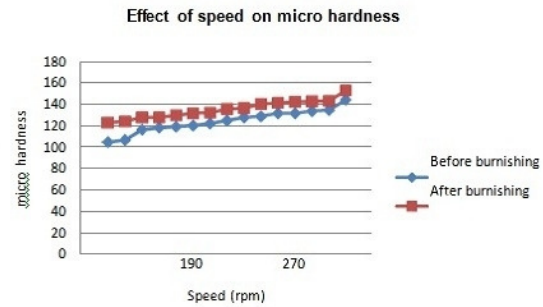
Std order	Run order	Speed (rpm)	Feed (mm/rev)	Number of passes	SR before burnishing ( $\mu\text{m}$ )	SR after burnishing ( $\mu\text{m}$ )	Micro hardness before burnishing	Micro hardness After Burnishing
13	10	190	0.42	2	1.44	0.74	104.8	132.2
11	11	190	0.22	3	1.96	0.80	120.1	142.4
3	12	135	0.65	2	1.82	0.85	116.2	130.2
9	13	190	0.22	1	1.74	0.88	128.9	130.4
14	14	190	0.42	2	1.99	0.82	122.4	138.2
7	15	135	0.42	3	1.79	0.72	131.6	144.5

## 5. RESULTS



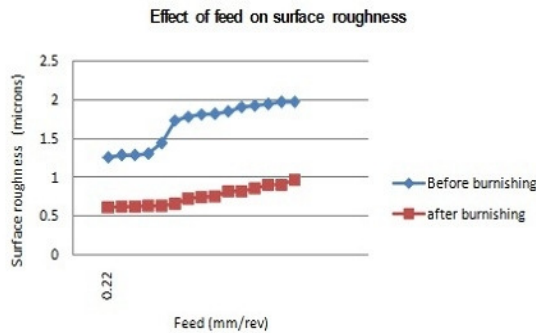
**Fig. 3. Effect of speed on surface roughness**

Fig. 3 and Fig. 4 show the graphs for effect of speed on surface roughness and micro hardness respectively. Before the specimen is burnished, it is seen that with increase in speed the surface roughness is decreasing up to  $1\mu\text{m}$  at 190 rpm and with increase in speed the surface roughness increases to  $2\mu\text{m}$  at 270 rpm. With further increase in speed



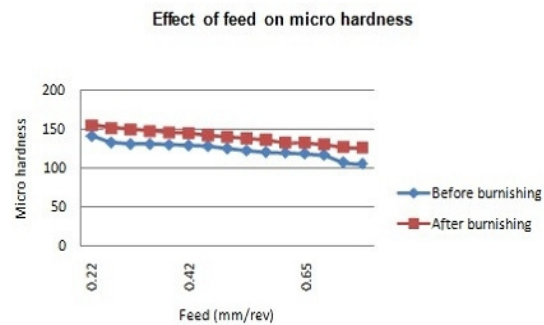
**Fig. 4. Effect of speed on micro hardness**

the surface roughness decreases. After burnishing, it is seen that the surface roughness is least at 270 rpm and further increases with increase in speed. Before burnishing, micro hardness is 120 VH at 135 rpm and it increases to 130 VH at 270 rpm. After burnishing micro hardness is 130 VH and 145 VH at 190 rpm and 270 rpm respectively.



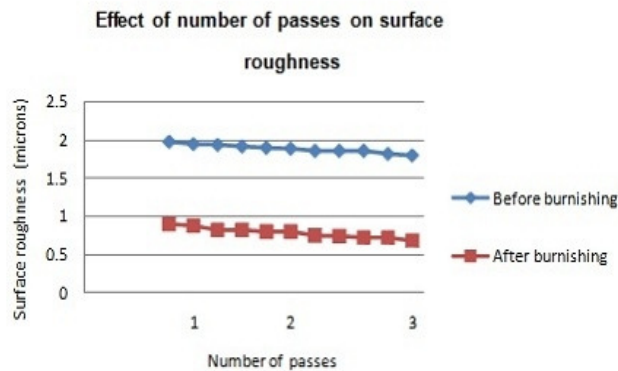
**Fig. 5. Effect of feed on surface roughness**

Fig. 5 and Fig. 6 show the graphs for effect of feed on surface roughness and micro hardness respectively. At 0.22 mm/rev, the surface roughness is least in both unburnished and burnished specimen. Micro hardness is 140 VH and



**Fig. 6. Effect of feed on micro hardness**

150 VH at 0.22 mm/rev for unburnished and burnished specimen respectively. At 0.42 mm/rev, micro hardness is 125 VH and 135 VH for unburnished and burnished specimen respectively.



**Fig. 7. Effect of number of passes on surface roughness**

Fig. 7 and Fig. 8 shown the graphs for effect of number of passes of burnishing tool on surface roughness and micro hardness respectively. Before burnishing, surface roughness is as much as 2 $\mu$ m after 1st pass which subsequently decreases to 1.8 $\mu$ m and 1  $\mu$ m after 2nd and 3rd pass respectively. After burnishing, the surface surface obtained is 1  $\mu$ m and it decreases to 0.75  $\mu$ m and 0.5  $\mu$ m after 2nd and 3rd pass respectively. It is seen that for an unburnished specimen, after 1st pass the micro hardness is 100 VH and it increases to 120 VH and 140 VH after 2nd and 3rd pass respectively. For a burnished specimen, the micro hardness increases to 125 VH after 1st pass, 140 VH after 2nd pass and 150 VH after 3rd pass.

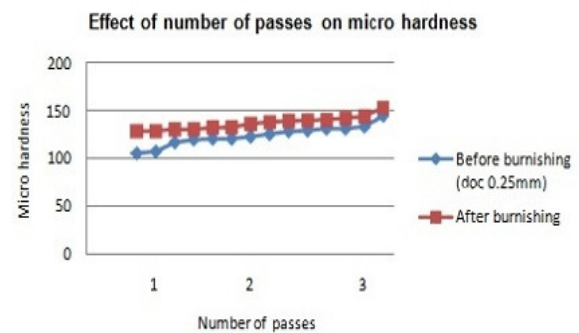
## 6. CONCLUSION

The effect of speed has a major effect on surface roughness after burnishing for AA6082 alloy. At 270 rpm, surface roughness is the lowest beyond which it increases significantly. The effect of speed on micro hardness is quite linear in nature. After burnishing, the range of micro hardness increases for AA6082 alloy. As the speed increases, there is a gradual and linear increase in micro hardness. Feed has a significant effect on for surface roughness and micro hardness. As feed increases, surface roughness increase and micro hardness decrease in both unburnish and burnished specimen.

The effect of number of passes of roller burnishing tool on surface roughness and micro hardness is quite major. The range of surface finish decreases quite significantly after burnishing and with increase in number of passes there is a gradual decrease in surface roughness. The effect of number of passes on micro hardness after burnishing with compare to unburnished specimen is quite marginal.

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**Fig. 8. Effect of number of passes on micro hardness**

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# Wall Climbing Tech-Chameleon Robot

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**Abstract:** In today's era, disguise robots play an important role not only in military applications like to spying, but also serve to save humans and losses to property during disasters. In this paper a method of constructing a wall climbing spy robot that changes its color with respect to surrounding surface with a wireless camera for surveillance purpose has been proposed. Communication with user is achieved by using RF module. For wall climbing a combination of suction pump and DC motors has been implemented. For effective color changing capability a LCD screen is used. LCD screen changes its display according to surrounding.

**Keywords:** RF module, Suction pump, LCD module.

## 1. INTRODUCTION

The purpose of wall climbing robots is climbing on the vertical surfaces. These robots are required to have high, adaptability and mobility according to the surroundings in addition to robust & efficient attachment and detachment. The robot can automate tasks with an extra degree of precision for human safety in a cost effective manner. The robot can move in all the four directions forward, backward, left and right. The other locomotion capabilities include linear movement, turning movement, lateral movement, rotating and rolling movement. Apart from the reliable attachment principle, the robot should have low self weight and high payload capacity. The design and control of robot should be such that it can be operated from any place. A wireless communication link is used for high performance robotic system. The robots should have secure grip when it climbs on the vertical surfaces. The robots should adopt to different surface environments from steel, glass, ceramic, wood, concrete etc. with low energy consumption and cost. Wall climbing robots are special robots that can be used in a variety of applications like inspection and maintenance of surfaces of sea vessels; oil tanks of high raise building etc. To increase the operational efficiency and to protect human health and safety in hazardous tasks make the wall climbing robot a useful device. spying plays important role in security of any nation[1]. With the improvement in technology spying is getting more & more advanced and highly efficient. The work is inspired from the color changing ability of a Chameleon. In addition, the proposed bot is also capable of wall climbing using suction devices. A RF transceiver is also used to increase the range of communication between transmitter and receiver.

The main aim of the project is to design a robot which has better range and camouflaging features in order to adapt to the surroundings.

The proposed design has been implemented using Atmega16 microcontroller, which provides better stability and higher processing speed as compared to the other traditional microcontrollers. It has one inbuilt ADC port to which analog output of a sensor can directly feed. This feature in turn also aids in reducing complexity and overall cost of the system



Fig. 1. A Typical Chameleon

## 2. METHODOLOGY

The system is divided into two parts i.e.

### 2.1. Transmitter.

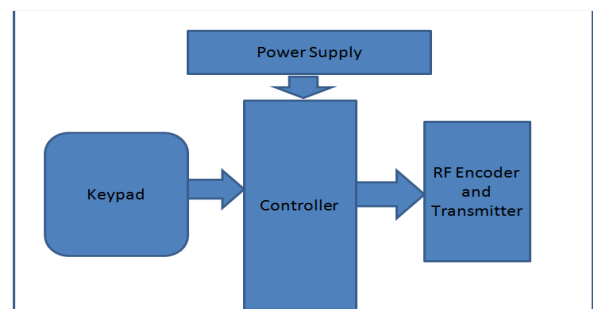


Fig. 2,

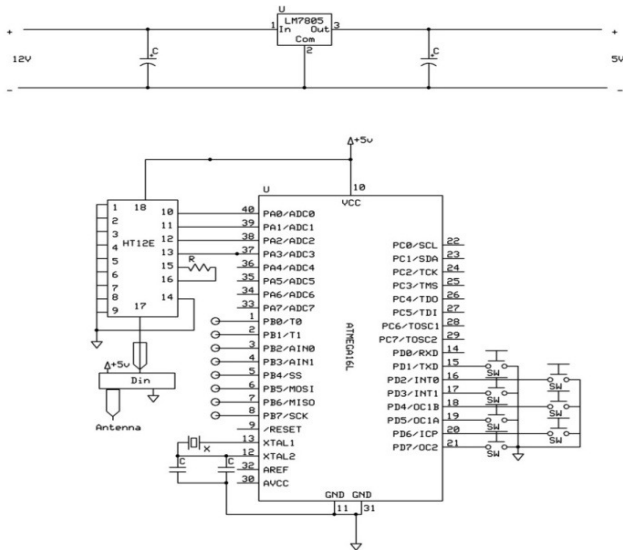


Fig. 3.

## 2.2. Receiver.

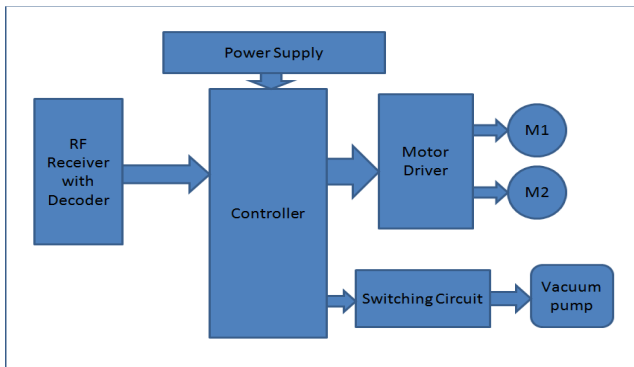


Fig. 4.

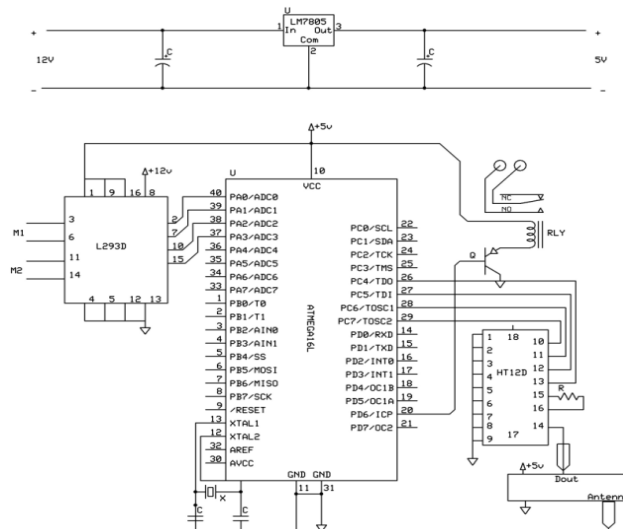


Fig. 5.

Basic structure of transmitter is shown in fig2. It consists of atmega16 microcontroller as heart of the system. As shown in fig.2 keypad interfaced to the port A of microcontroller, gets data from the user and then it is transferred via RF module to destination. RF transceiver is interfaced to the pin no 14 &15 of the port D which serve asRxD(Receive Data) andTxD(Transmit Data) pins. At the robot side, RF receiver receives the signal from transmission module which is decoded by Atmega16 microcontroller. These signals are processed by giving them as input to the L293 Motor driver IC.Then the robot moves according signal received. Color sensor detect a surrounding color, provide feedback to the microcontroller and then microcontroller again generates signals to illuminate LCD screen. Wireless camera captures real time videos and images of the surroundings and transmitthe same to the operator.

## 3. COMPONENT DETAILS

### 3.1 ATmega16

**ATmega16** is an 8-bit high performance microcontroller with low power consumption. It is based on enhanced RISC (Reduced Instruction Set Computing) architecture with 131 powerful instructions. It can work on a maximum frequency of 16MHz and has 16 KB programmable flash memory, static RAM of 1 KB and EEPROM of 512 Bytes. The endurance cycle of flash memory and EEPROM is 10, 000 and 100, 000, respectively. ATmega16 is a 40 pin microcontroller. There are 32 I/O (input/output) lines which are divided into four 8-bit ports designated as Port A, B, C and D.

### 3.2 RF module

The RF module frequency range varies between 30 kHz & 300 GHz. In this RF system, the digital data is represented as variations in the amplitude of carrier wave(Amplitude Shift Keying (ASK)).

Transmission through RF is better than IR (infrared).The signals through RF can travel through larger distances making it a better choice for long range applications.

This RFmodule comprises of an RF Transmitter and an RF Receiver. The transmitter/receiver (Tx/Rx) pair operates at a frequency of 434 MHzAn RF transmitter receives serial data and transmits it wirelessly. The transmission occurs at the rate of 1Kbps - 10Kbps.The transmitted data is received by RF receiver operating at the same frequency as that of the transmitter.

### 3.3 LCD screen

LCD screen is a flat-panel display that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be

displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, etc. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in nearly all applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence.

### 3.4 Suction Pump-

12V motor  
12W operation  
¼" barbs  
0-16" Hg vacuum range

### 3.5 Motors—

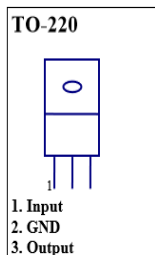
- DC supply: 4 to 12V
- RPM: 100 at 12V
- Cost effectiveness of the injection moulding process.

### 3.6 Three terminal positive voltage regulator IC-

ABSOLUTE MAXIMUM RATINGS (Ta= 25° C)

Characteristic	Symbol	Norm	Unit
Input Voltage	Vin	V	35
Maximum Dissipated Power(with heat sink)	Ptot(max)	W	15
Maximum Dissipated Power(without heat sink)	Ptot(max)	W	1.5
Thermal Resistance Junction to Case	OjC	°C/W	5.0
Thermal Resistance, Junction to Air	OjA	°C/W	65
Junction Temperature	Tj	150	°C

Tc=-45 +70°C



### 3.7 Decoder IC-

Operating voltage: **2.4V~12V**

- Low power and high noise immunity CMOS technology
- Low standby current
- Capable of decoding 12 bits of information
- Pair with HolteK
- 212 series of encoders
- Binary address setting

- Low density, lightweight, low inertia. Relatively low coefficient of friction.



Fig. 6



Fig. 7.

- Received codes are checked 3 times

### 3.8 HT12A/HT12 Encoder IC-

- Operating voltage : 2.4V~5V for the HT12A  
2.4V~12V for the HT12E
- Low power and high noise immunity CMOS technology
- Low standby current: 0.1
- A (typ.) at VDD=5V

### 3.9 L293, L293D Quadruple Half-H Drivers

- Unit rode L293 and L293D Products Now From Texas Instruments
- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply Internal ESD Protection
- Thermal Shutdown High-Noise-Immunity Inputs Functional Replacements for SGS L293 and SGS L293D
- Output Current 1 A Per Channel (600 mA for L293D)  
Peak Output Current 2 A Per Channel (1.2 A for L293D)

## 4. WORKING PRINCIPLE

### 4.1 Wall Climbing-

It is done with the combination of motors and suction pump. The suction pump is turned on with the help of transmitter. Once turned on, the suction cap creates a vacuum and the model (both) gets stuck to the wall. Now motors play their role and the bot slides. Motors slide it up, down, right and left according to instruction given by the user. In this way wall climbing can be done. But this needs a high accuracy as the amount of pressure and bot weight has some fixed ratio for climbing purpose. The adhesion force is very less between suction cap and wall due to which glass surface is more preferable.



Fig. 8

### 4.2 Color changing-

This ability is produced with the help of LCD screen and a rear camera. The rear camera takes a video of the surface and displays the same on the screen. Due to this, an illusion of the surface gets created which in turn hides the bot.

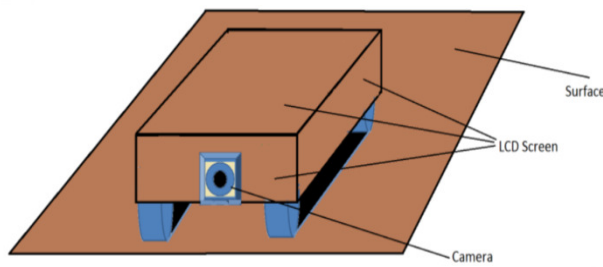


Fig. 9

## 5. RESULT & CONCLUSION

A working model of wall inspection robot based on

mechanism of suction pump with hiding capability can thus be developed. The robot, composed of pair of driving mechanisms, can automatically change its color depending upon color of surface and can handle payloads below 2k.

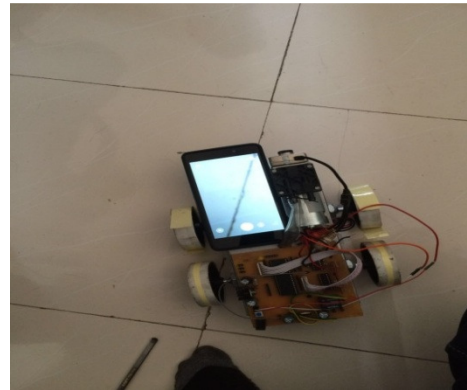


Fig. 10

A robot is created which can climb and hide acquainting to any condition. It's a adaptable robot which can work in any conditions efficiently. The color changing ability of the bot perfectly defines spying. Since human life is always valuable, this robot can be the substitution of soldiers in war areas. It is inspired by creatures such as chameleon. The Camouflage robot can also be used in star hotels, shopping malls, jewelry showrooms, and operation aids, rescue crews during disasters or at places such as where there can be threats from intruders or terrorists.

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# Study of Data Frame Bit Pattern Based Power Consumption Behavior in Zigbee Transmission

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**Abstract :** In recently emerged network communication protocols, zigbee based on IEEE 802.15.4 standard is widely used for its low power consumption, low cost, low data rate, highly reliable, multi hop data transmission, low latency and simple protocol for global implementation. Zigbee also presents some potentially interesting features for supporting large-scale ubiquitous computing applications like timeliness and scalability. Zigbee module is used as wireless communication device in wireless sensor networks. Many researchers and scientist has been tried to find out factors which affects power consumption behavior of the module. They have worked on different modulation schemes, different routing schemes, etc. In this paper we have introduced a novel idea to prove a relationship between different types of bit patterns to be transmitted and power consumption in the zigbee transmission process. In this paper the study is focused on bit pattern based power consumption behavior seen in the transmission by the zigbee module. Particular kind of data pattern may draw a more current from the power supply unit than the other kind of data pattern configured as data bit stream.

**Keywords:** Bit pattern, Wireless Sensor Network, Zigbee.

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## 1. INTRODUCTION

In wireless sensor networks, a node consists of a sensor (sometimes more than one sensor) which is capable of gathering information about physical parameter, an analog to digital converter device, a micro-controller for processing of data and also contains the communication module to communicate with the base station or with the other nodes of the network. The advances in technology have resulted in less expensive low power communication devices. In order to communicate the data of the sensed parameter the node also contain transceiver type communication module like zigbee, blue-tooth, Wi-Fi or any other this kind of device. The nodes of the wireless sensor networks can be powered by batteries. Thus individual devices in the network are inherently resource constrained and mainly power constrained. In many applications battery replacement for a node is not feasible. Considering one specific example, In the sensors of Body Area Network (BAN) variable data packet size has been used. Some of them also use full RF data packet size. In-Body communication type where, medical implanted sensors communicate with the on-body sensors [Tanmoy Mitra and Sarbani Roy-2017]. In In-Body communication energy resource is main considerable factor, where replacement of battery is not possible, therefore life of battery defines life-time of node. Our main aim is to design a communication scheme which will give efficiently utilization of energy in WSN. For reliable prediction of the lifetime of the sensor node, analysis of the power consumption is necessary. In order to achieve this we have tested energy consumption in the transmission of the

communication module, which is one of the considerable parameter in the total power consumption of any node. In WSN each node has very limited power and it is mostly battery supplied [Debmalya Bhattacharya and R. Krishnamoorthy-2011]; In the various areas of application of many systems, power consumption and others has been a challenge and treat to the sensor node deploy into the field for monitoring and others functionality. Although, the use of battery for sensor nodes powered is greatly eases deployment of the nodes in the constrained environment or hazardous area where the applications are required through wireless network, but the battery replacement shows to be unpractical [Ajao A. Lukman, Agajo J., Kolo J. Gana, Inalegwu C. Ogbale, and Edem E. Ataimo-2017].

## 2. INTRODUCTION OF ZIGBEE PROTOCOL

Zigbee emerged in the recent decades is a short distance with low data rate of wireless network communication technology. It is expected to support applications such as remote monitoring, home control and industrial automation [Ding G., Sahinoglu Z., Bhargava B., Orlik P, and Zhang Z.-2006]. Zigbee is based on the IEEE 802.15.4 standard and specifies the MAC and physical layers. Physical layer supports three radio bands: 2.4 GHz band (Worldwide – 250 Kbps) with 16 channels, 915 MHz band (Americas – 40Kbps) with 10 channels and 868 MHz band (Europe – 20Kbps) with a single channel [Maria Dimou, Theofilos Kossyvakis, Costas Chaikalis, Konstantinos P. Tsoukatos, Charalampos Liolios and Vasileios Vlachos-2016]. MAC layer controls the access to the radio channel using the Carrier Sense Multiple Access with Collision Avoidance



(CSMA-CA) mechanism [Maria Dimou, Theofilos Kossyvakis, Costas Chaikalis, Konstantinos P. Tsoukatos, Charalampos Liolios, and Vasileios Vlachos-2016]. Zigbee's transmission range varies from 1 to 100m and it can support up to 65536 nodes [M.C. Huang, J.C. Huang, J.C. You and G.J. Jong, -2007]. A zigbee modeled system has to be designed which will comprise of the following modules [Archana R.Raut and Dr. L.G.Malik-2011]:

- Transmitter module
- Receiver module

Zigbee module is used in two data format operating modes: Application Transparent (AT) and Application Programming Interface (API). In both the modes of the digital communication, AT mode is rarely used transparent serial communication mode when the module locally connected to an intelligent device like PC or microcontroller, in this mode transmitter simply passes information to receiver exactly as it received and it is

transmitted without frame structure, just like serial cable replacement. While in API operating mode, a protocol is defined for exchange of information, data frame has been structured in packets before transmission of the information. API mode allows you to form larger networks. API mode is most suitable to create sensor networks to perform tasks such as collection of data from multiple locations, controlling devices remotely, or automating industrial processes. Start delimiter indicates starting point of the frame structure. Length indicates number of bytes between the length and the checksum. Frame type indicates that the frame is transmitting request type frame or an explicit Rx indicator frame or any other type of frame. Frame ID identifies the data frame for the host to correlate with a subsequent transmit status frame, setting frame ID '00' will disable response frame. 64-bit destination address is the address of the destination zigbee. For co-ordinator address 0x0000000000000000 is used and for broadcast address 0x000000000000FFFF is used. Checksum is hash sum of frame data bytes.

Start Delimiter	Length		Frame Data								Checksum
			Frame type	Data(payload)							
1	2	3	4	5	6	7	8	9	...	n	n + 1
0x7E	MSB	LSB	API frame type	Frame-type-specific data							Single byte

**Fig. 1. API frame structure**

The experiment is done with zigbee using world-wide radio band 2.4 GHz which is specified for data speed of 250 Kbps. Offset Quadrature Phase Shift Keying (OQPSK) digital modulation technique is used for inter-module communication. We have used zigbee modules of S2 series in the experiment. For pre-communication configuration we utilized X-CTU (XBee Configuration and Test Utility) Software. One Zigbee module configured as coordinator and another as router or end device. We have done experiments in both the operating modes: AT and API. Other configuration detail of API mode is summarized in

table-1. In both the operating modes Power consumed by the transmitter module should remain independent, whatever bit pattern may be transmitted. The device are generally used for remote sensor monitoring and mostly battery operated, therefore power consumption must remain as low as possible. We have considered RF data packet size of 255 bytes-full packet, which is mostly seen in the heterogeneous sensors based wireless sensor networks.

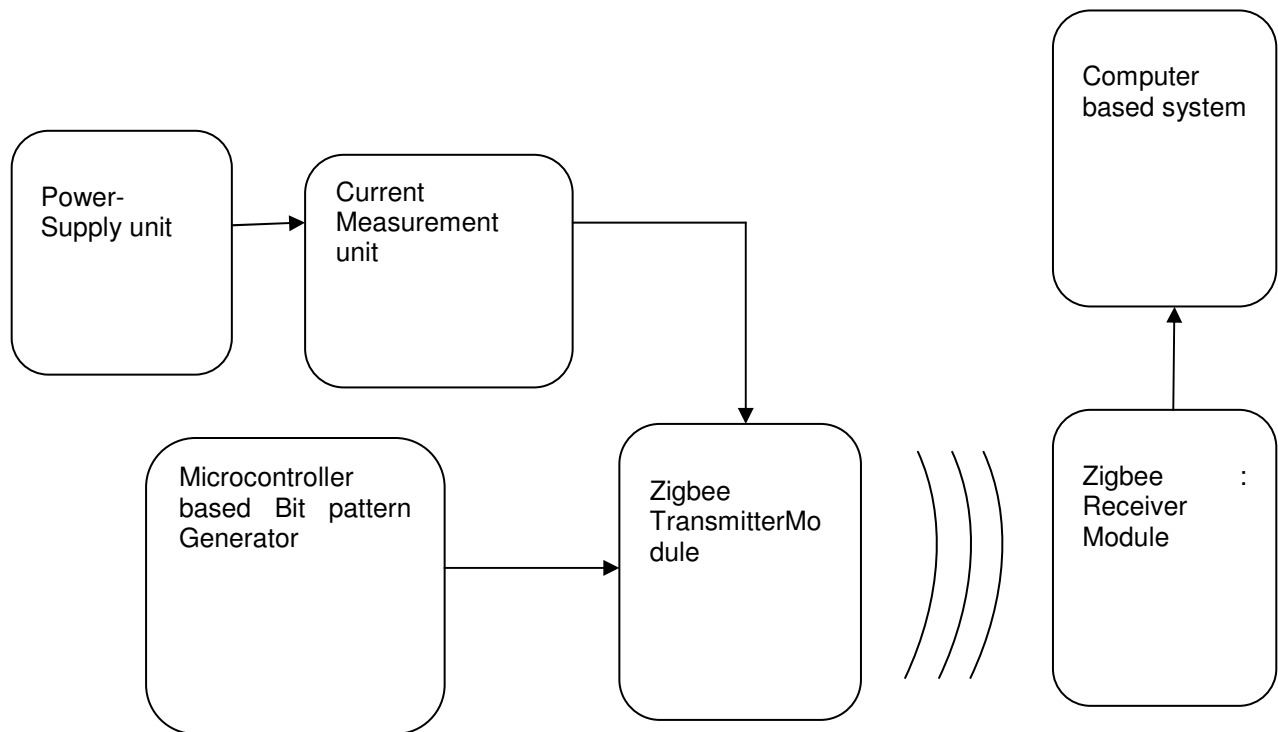
In any kind of digital communication bits in the form of 0s and 1s are transmitted from transmitter to the receiver. Data stream is in the form of any combination of 0s and 1s.

**TABLE 1: Zigbee pre-transmission configuration parameters**

	Operating mode	API	
01	Start delimiter	0x7E	
02	RF Data starts from	0x000B	

	Operating mode	API	
03	RF Data ending at	0x010B	
04	RF data (volume)	255 Bytes	
05	64 bit destination address	0x XX XX XX XX XX XX XX XX	X=0 or 1
06	Frame type	0x00	
07	Frame ID	0x01	

### 3. EXPERIMENTAL SET-UP



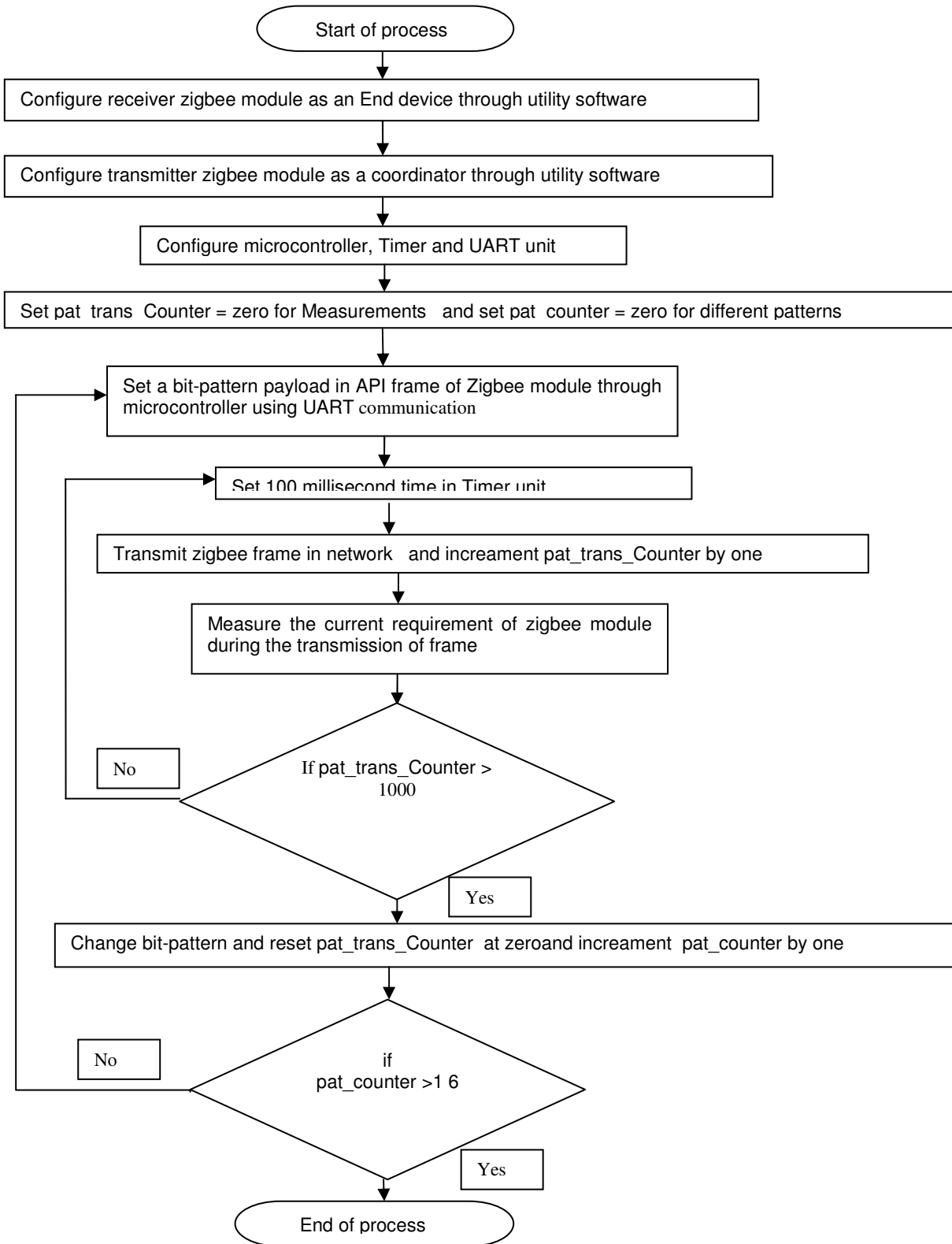
**Fig. 2. Block diagram of Experimental Set-up**

A zigbee module which is configured to work as a transmitter is connected to a UART port of a microcontroller board for the transmission of the different data types. Power requirement of the zigbee communication module is fulfilled by a 5V battery (supply from a USB of a laptop) or a power bank. a current measurement system (multimeter) connected in series of the power supply and zigbee module as shown in block diagram of figure-2. Generally microcontroller provides converted digital data from the sensors, but in our case sensors are not connected to the microcontroller and different types of bit pattern of the data are generated through software programming. XCTU software has been used for configuration of zigbee. API operating mode has been selected in order to transmit a

data frame. The transmitter made a coordinator and the receiver made end device. Different data frames are generated by the frame generator of the microcontroller. 1000 frames are transmitted for each pattern and time interval between two frames is set 100mS. Each byte in the frame includes two nibbles and each frame includes 255 bytes. All nibbles of the frame of RF data is filled by 1s and current measured by the current meter. Then after all nibbles of the frame of RF data is filled by all 0s and current measured. Then different combinations of 0s and 1s in the nibbles are configured as shown in graph of figure: 4. differently obtained results are compared and tried for few other data types.



#### 4. WORKING METHODOLOGY

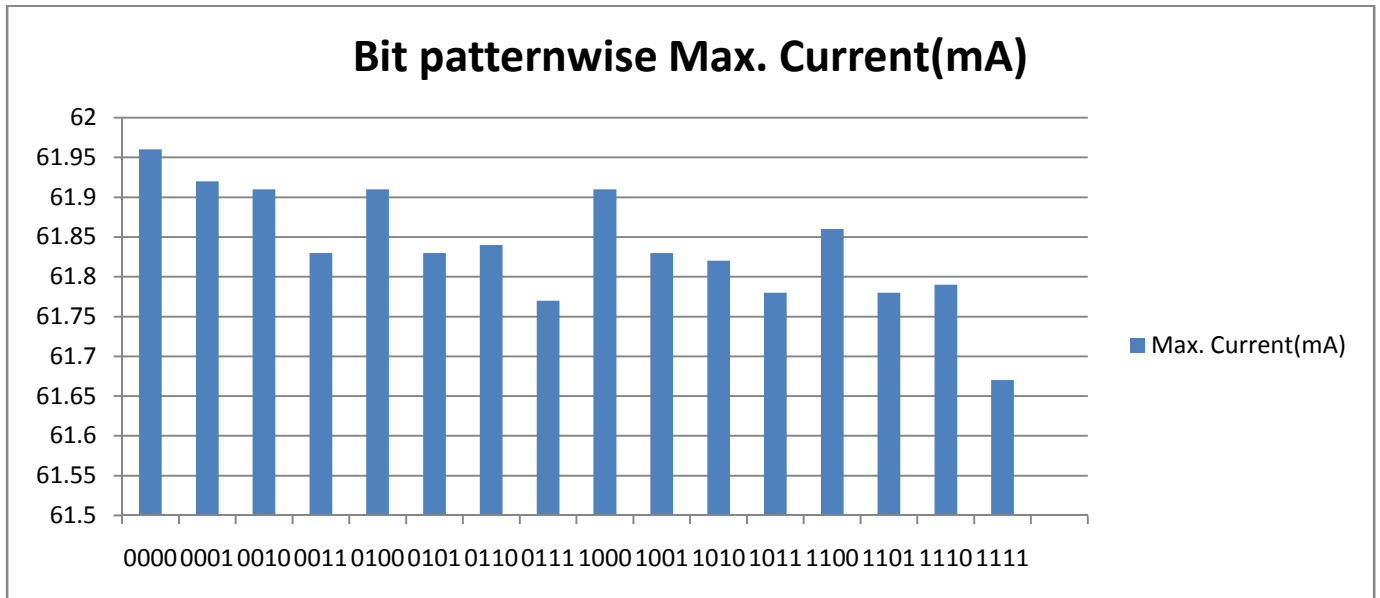


**Fig. 3. Process Flow-chart:**

## 5. RESULTS OF THE EXPERIMENTAL WORK

**TABLE 2: Current Measurements for Different Bit Patterns**

No.	Bit pattern in RF Data frame	Max. Current drawn without RF data in payload (Transmission mode ON)	Max. Current drawn by specified data pattern with full payload	Difference of current consumption of specified data pattern compare to no payload transmission.
01	0000 0000	60.47 mA	61.96 mA	1.49 mA
02	0001 0001	60.47 mA	61.92 mA	1.45 mA
03	0010 0010	60.47 mA	61.91 mA	1.44 mA
04	0011 0011	60.47 mA	61.83 mA	1.36 mA
05	0100 0100	60.47 mA	61.91 mA	1.44 mA
06	0101 0101	60.47 mA	61.83 mA	1.36 mA
07	0110 0110	60.47 mA	61.84 mA	1.37 mA
08	0111 0111	60.47 mA	61.77 mA	1.30 mA
09	1000 1000	60.47 mA	61.91 mA	1.44 mA
10	1001 1001	60.47 mA	61.83 mA	1.36 mA
11	1010 1010	60.47 mA	61.82 mA	1.35 mA
12	1011 1011	60.47 mA	61.78 mA	1.31 mA
13	1100 1100	60.47 mA	61.86 mA	1.39 mA
14	1101 1101	60.47 mA	61.78 mA	1.31 mA
15	1110 1110	60.47 mA	61.79 mA	1.32 mA
16	1111 1111	60.47 mA	61.67 mA	1.20 mA



**Fig. 4. Graph of bit pattern Vs Max. Current Consumption**

## 6. CONCLUSION

Conclusion leads to the following points. Where sequence of 1s appears in the data frame, power consumption is less and where sequence of 0s appears in the data frame power consumption increases. Both operating modes AT and API show almost same behavior. Current consumed in transmission is dependent on the number of 0s and 1s included in each nibble of data. As number of 0s increases in the bit pattern of a nibble, the current consumption and hence power consumption increases as shown in table: 2.

In zigbee transmission modulation envelope pattern has been seen in such a way that when 0s pattern is transmitted, area under the curves covers, more than when 1s pattern has been transmitted. Data pattern of 0s draw more power than power drawn by data pattern of 1s. Thus, in a data frame bit pattern based power consumption behavior has been seen. This is undesirable feature for a healthy digital communication system of wireless sensor network. The research work is focused for single node, in multi-node networks the power consumption or saving will be multiplied by number of nodes, which draws our focus about considerable amount of energy.

Future work: Overall reduction in energy efficiency will be proved when more numbers of 1s and a very less number of 0s are continuously seen in the data frame. Finally we can suggest finding out such a energy efficient design scheme, which is applicable to minimize power consumption, thus enhancing the life-time of the power supply of the node in wireless sensor networks. This can be fulfilled by finding the better energy model as well as more efficient modulation scheme.

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# Study of Springback Effect in Sheet Metal Bending Process and its Influencing Process Parameters: A Review

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**Abstract:** One of the sensitive feature of sheet metal bending is elastic recovery called springback effect. There are numerous parameters which affect this springback, so accurate prediction and controlling of springback is essential while designing the tools for bending. This article provides an intensive review on the research work of influencing process parameters on the springback behaviour in sheet metal bending processes. The Review includes numerical, analytical and experimental aspect of the relevant works that clarify the effect of several process parameters noted as punch radius, die opening, bending angle, coating thickness, orientation of sheet, blank holder force over the springback effect. Finally, concluded the most influencing process parameters in sheet metal bending over the springback effect.

**Keywords:** Sheet Metal Bending, Springback effect.

## 1. INTRODUCTION

Common Air type of bending is mostly used in sheet metal industries today. The bending processes of sheet metal are widely used to produce structural stamping parts. Today Automobile industries depend largely on sheet metal forming processes to manufacture components. The popularity of sheet metal products is because of their light weight, great interchangeability, good surface finish and low cost. In this process the blank is deformed under punch pressure in a die along one axis. The blank is initially deformed in elastic region and as the process continue of deformation it will enter into plastic deformation zone, thereby changing its shape. In bending process, the bending load increases until the elastic limit of material is exceed after that load increases in plastic one and deformation occurs and thus sheet metal can be formed. Specifically, stress generated in the blank is greater than the yield strength but lower than the UTS of material. The blank initially deform where the bending moment is maximum. During bending process the stress distribution in sheet metal is of linear nature i.e. maximum at outer surface and zero at neutral axis, so outer surface is in tension and inner surface is in compression.

All materials have a finite modulus of elasticity, plastic deformation is followed by some elastic recovery as the punch load is removed and this phenomenon is called springback. In bending process, springback affects the final shape and geometry of the workpiece when the punch is removed. This springback causes deviations in the desired final shape and thus the part after the springback may not be within tolerance limits, so not suitable for the application for which it was designed.

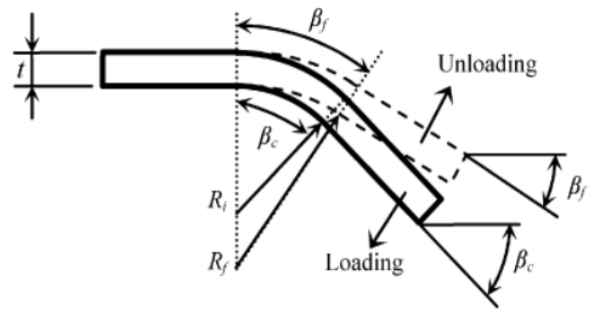


Fig. 1. Springback Effect in L Bending [12]

The final bent radius ( $R_f$ ) larger than loading situation and the final bent angle after springback ( $\beta_f$ ) is smaller (Fig. 1). Springback amount may be defined either by a non-dimensional springback factor ( $K_r$ ), which is the ratio between the final unloading bending angle ( $\beta_f$ ) and the loading bending angle ( $\beta_c$ ), or by a springback angle ( $\Delta\beta$ ), which can be expressed by Eq. (1):

$$\beta_c = \beta_f + \Delta\beta$$

Angle and radius are related one to each other; hence springback can be estimated approximately by Eq. (2). This equation has turned into a simplified reference expression for springback computation, assuming constant thickness and arc length.

$$\frac{R_i}{R_f} = 4 \left( \frac{R_i S_Y}{Et} \right)^3 - 3 \left( \frac{R_i S_Y}{Et} \right) + 1 \quad (2)$$

Where  $R_i$  is the radius in loading state,  $R_f$  the final radius,  $t$  the thickness,  $S_y$  the yielding stress and springback decreases with it and  $E$  is the Young's modulus.

In bending the ductility of the sheet metal plays very important role. If the ductility is lower, the minimum bend radius is larger at the same time a state of biaxial stresses in bend region may also reduce ductility on outer fibres. As width to thickness ratio value is larger ( $w/t$ ) of the sheet, the state of biaxial stress can be expected. Greater is the  $w/t$  ratios reduce the critical strain required for fracture resulted the bend radius will be higher. Narrow sheets gets crack at the edge when the state of stress along edge is more biaxial than at centre. Wider sheets, when subjected to larger radius of bend, undergo crack at centre because the centre is subjected to more biaxial state of stress. In order to increase the minimum radius, sheets are polished or ground.

## 2. LITERATURE SURVEY

Several experimental and numerical studies have been done to study the springback effect in sheet metal forming process. M. L. Garcia-Romeu et al (2007) presents new springback graphics for air vee bent sheet metal parts. He conducted an experimental works in two stages on two different materials. This work presents same kind of useful graphics that relate spring back with the main parameters that have influence over phenomenon [M. L. Garcia-Romeu et al (2007)]. D Vasudevan et al (2011) study the springback behaviour of electro galvanised steel sheets during air bending process. Experiment conducted to show the influence of various process parameters over springback effect.

Here mainly focuses on the influence of coating thickness over springback along with other process parameters, result shows the springback increases with coating thickness [D Vasudevan et al (2011)]. Viorel Paunoiu et al (2015) measures the springback by new experimental device against influencing process parameters as bending angle, the punch radius and sheet metal thickness [Viorel Paunoiu et al (2015)]. K. Dilip Kumar et al (2014) conducted an experiment to determine the springback and thinning effect of aluminium sheet metal during L Bending operation. He found one critical clearance between punch and die and observed the effect of it. It shows beyond a particular clearance the springback and thinning effect were linearly increasing, however below critical clearance scratches on the surface of the sheet metal were seen due to wear [Vasudevan et al (2011)]. K. Yilamu et al (2010) study and investigate the bending characteristics such as uniformity in sheet thickness change and the bending angles of the sheet before/after springback. Conducted both experimental and analysis work to analyse the objective of experiment [K. Yilamu et al (2010)].

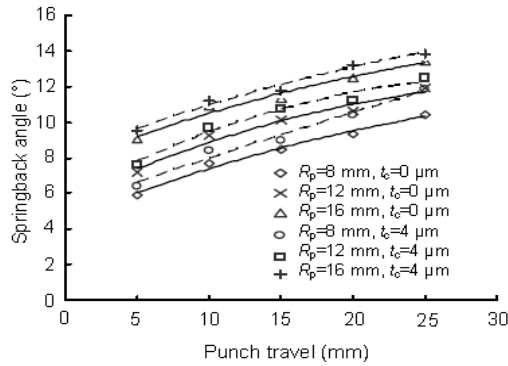
Hezong Li et al (2010) to investigate the springback behavior of pure aluminum foils, scaled micro bending

experiments with different thicknesses ranging from 25 $\mu$ m to 500 $\mu$ m were carried out. In the experiments, it is observed that springback angle increases with decreasing foil thickness, which indicates obvious presence of size effects, and is attributed to plastic strain gradient hardening. A constitutive model is proposed to predict the springback angle after micro bending both by analytical expression and by FE simulation [Hezong Li et al (2010)]. M.H. Parsa et al (2014) in this research, the effect of punch radius on springback in the early stage of V-die bending process of aluminum/polypropylene/aluminum sheets is studied both numerically and experimentally. To analyse springback behavior, contact pressure evolution during bending process was studied using numerical simulation [M.H. Parsa et al (2014)]. Daw-Kwei Leu et al (2016) study proposed a simplified approach to distinguish between spring-back and spring-go in free U-die bending process of SPFC 440 sheets [M.H. Parsa et al (2014)].

R. Narayansamy et al (2009) describes the development of regression based mathematical models for the prediction of springback in air bending process of interstitial free (IF) steel sheet with five input process parameters and the springback as output process parameter to develop the quadratic model to predict the output [R. Narayansamy et al (2009)]. Zhang dong-Juan et al (2007), in this paper an analytical model is proposed which takes into account the effects of contact pressure, the length of bending arm between the punch and die, transverse stress, neutral surface shifting and sheet thickness thinning on the sheet springback of V-bending. The predicted results by this analytical model indicated that the contact pressure and transverse stress have much effect on the springback when the bending is less than five [Zhang dong-Juan et al (2007)]. Faiez Gassara et al (2009), an optimization algorithm using Gauss-Newton method was developed by coupling the Abaqus/standard code and Python script which is an object-oriented language. For a given bending process problem, the proposed algorithm allows for the optimization of a set of material and/or process factors in order to minimize the work piece springback [Faiez Gassara et al (2009)].

## 3. INFLUENCING PROCESS PARAMETERS ON SPRINGBACK BEHAVIOUR

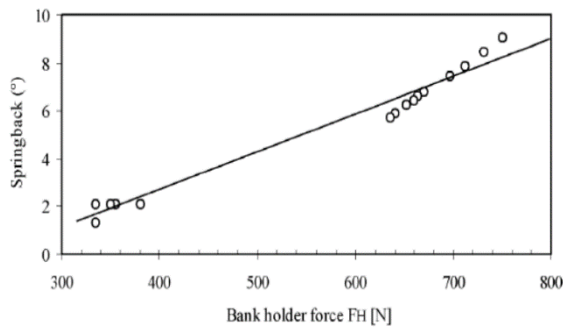
**Punch Radius:** It is found that the springback angle increases with increasing punch radii because it is sensitive to the effective clearance between the punch and the die. The effective clearance is the distance between the point of sheet contacting with the die and the point where the sheet leaves contacting with the punch nose radius. As the punch radius is larger, the effective clearance would be smaller compared to a smaller radius thus springback increases with punch radius [Vasudevan et al (2011)].



**Fig. 1.1 Springback Vs Punch Travel in Vee bending [D Vasudevan et al (2011)]**

A bigger punch radius means that the stress in material will be lower because of bending and thus the ratio of plastic deformation Vs elastic deformation will be smaller so it increase springback effect [D Vasudevan et al (2011)]. From conducted experiment it is observed the springback effect Vs punch travel for different punch radii and coating thickness of electro galvanised steel sheet. Above graph show the increase of springback with punch radii [Vasudevan et al (2011)].

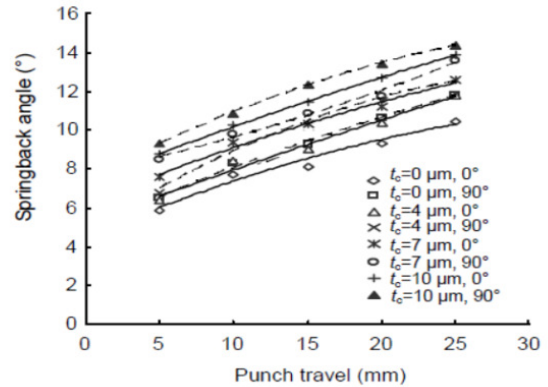
**Blank Holder Force:** Considering the influence of the blank holder (BH) force, it has been observed that the springback increases as the blank holder force increases. This phenomenon can be explained by the fact that with low subjecting force, the punch mostly generates bending stresses in the sheet, but as the blank holder holds the blank more tightly, the stresses induced by the punching phase become mostly tensile stresses.



**Fig. 2.1 Blank Holder force Vs Springback [Faiez Gassara et al (2009)] in L Bending of Sheet metal**

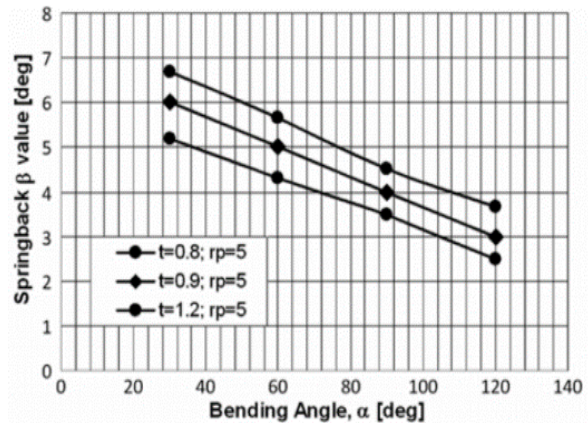
**Orientation of sheet:** Fig. 4.1 shows the springback angles for uncoated and coated steels in 0° and 90° orientations. It is seen that for both uncoated and coated sheets, the orientation has a significant influence on springback. The work blank along the 90° orientation exhibits more springback than the blank of 0° orientation. It is understood that the springback angle is a function of yield strength to

modulus of elasticity ratio ( $\sigma_y/E$ ), which will be higher for transverse direction than rolling direction².



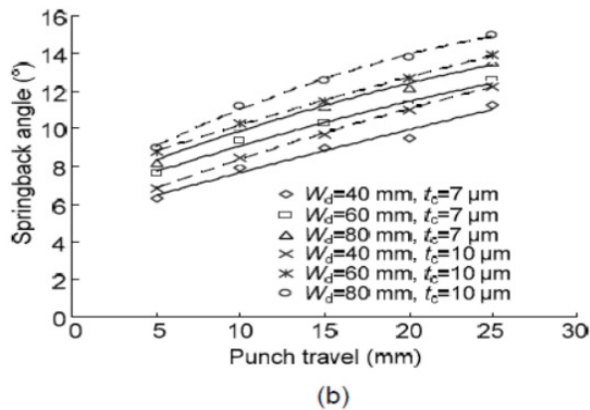
**Fig. 3.1 Variation of springback angles for different orientations [D Vasudevan et al (2011)]**

**Bending Angle:** The springback decreases when the bending angle increases regardless of material thickness. This happens because at certain punch radius as increases the interior bending angle, the tensile and compressive stresses on the inner and outer surface decreases thus springback decreases³. In addition the stress becomes uniform as thickness of sheet metal increases is also one factor of decrease of springback effect.



**Fig. 4.1 Springback values for different bending angle and thickness.**

**Die Opening:** Increase in die opening increases the springback angles for both uncoated and coated steels². After an experiment on EG sheet for different coating and different die opening and he found that the springback increases with die opening. This is because a large die opening increases the bending moment, and hence increases the springback. When the die opening is larger, there is a larger elastic displacement and rotation; therefore an increase in die opening increases the springback angle².



**Fig. 5.1 Variation of springback for different die angle²**

#### 4. CONCLUSIONS

There are number of process parameters which affect the springback effect in sheet metal bending. As per the discussion the parameters such as punch radius, blank holder force, orientation of sheet, bending angle and die opening has following effect on springback.

1. As punch radius increases the springback effect in sheet metal bending process increases.
2. Blank holder force also effective parameters for springback, as it increases the effect increases.
3. The work blank along the 90° orientation exhibits more springback than the blank of 0° orientation thus orientation has significant effect on springback.
4. There is inverse relationship between bending angle and springback, that is springback decreases as bending angle increases.
5. Increase in die opening increases the springback angles especially in sheet metal bending process.

Among these parameters the springback effect in sheet metal bending is mostly depend on bending angle thus it becomes most sensitive and influencing process parameter.

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# Conceptualization of Inspection Fixture for Front Axle Beam of a Truck

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**Abstract:** The growing demand of vehicles is a challenge for competitive automotive industries to deliver and mark their place in automobile sector. Manufacturing industries are coming up with new products and ideas to fulfill the customer's need. The time cycle for producing a vehicle has become very less thus increasing the production rate. To associate this speed of production, the industries have to accommodate techniques to manufacture parts, inspect and assemble a vehicle that can compensate time. In this paper, an inspection fixture is conceptualized and developed for inspection of front axle beam of a truck. Various operations are performed during the manufacturing of a forged beam. These operations are done at an angle to provide Castor and Camber angles to the vehicle. The accuracy of these operations is very important during assembly of the vehicle as the entire load of it lies on the axle. The inspection has to be done at the manufacturing unit itself that too in a single setup to reduce cycle time. Hence an inspection fixture is designed and arranged in production line to serve the purpose.

**Keywords:** Front Axle Beam, Inspection Fixture, GO and NOGO gauge, Cycle Time

## 1. INTRODUCTION

Increasing global competition among the manufacturing industries and changing customer requirements are bringing in a trend of varieties in product, shorter product life cycle, high quality and innovations (Bi and Zhang, 2001). Now a days, the manufacturing industries have identified the need of flexibility in design of fixtures (Ngoi, Tay and Wong, 1997). The challenging task of deciding the layout of the fixture and arrangement of pins and clamps are accomplished by means of computer aided methods. The tolerance of the fixture effects the quality of the processing results (Möhring and Wiederkehr, 2016). Fixture design

subject is often considered to have as much craft as analytical content (Kumar, Nee and Prombanpong, 1992).

In this paper, an inspection fixture for Front Axle Beam of TATA Truck model is conceptualized to inspect kingpin angle, spring saddle holes centre distance and distance between Pad Holes. Plug gauges are designed to check the dimensions of pad holes. A master jig plate is used for proper location of locating pins.

A beam axle, rigid axle or solid axle is a dependent suspension design, in which a set of wheels is connected laterally by a single beam or shaft as shown in Fig. 1 (William and Donald, 2017).

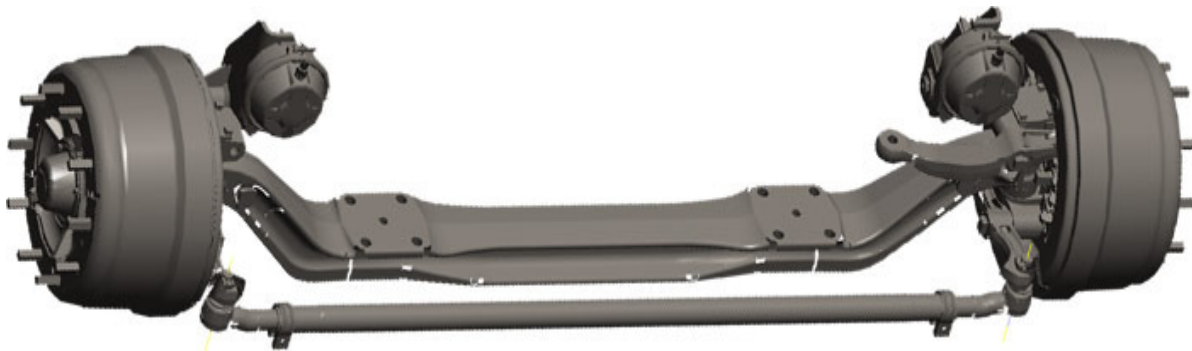


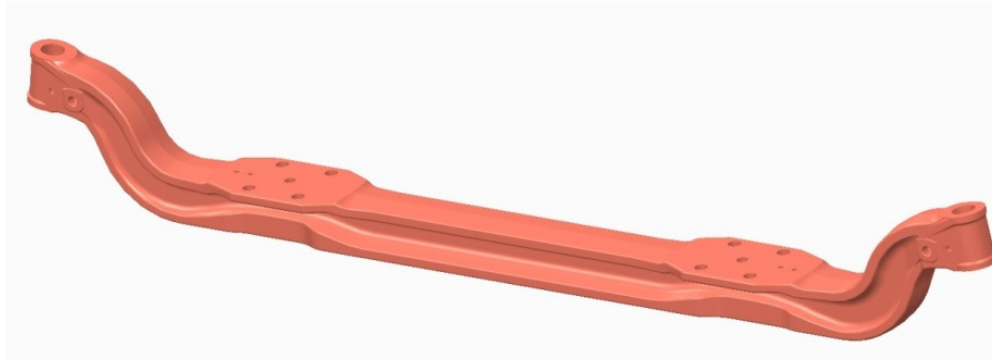
Fig. 1. 3-D assembly of Front Axle Beam of TATA model truck

## 2. COMPONENT DETAILS AND FEATURES TO BE INSPECTED

The Front Axle Beam which is to be inspected is a forged

component of 40Cr4 and is machined on UNISIGN 5 Axis CNC Machine, HMT Horizontal Milling Machine. The 3-D model of the component is shown in Fig.2.





**Fig. 2. 3-D model of the Front Axle Beam**

**TABLE I: Features to be inspected**

To be inspected	Dimension	Up tolerance	Low tolerance
King Pin Angle – LH	9.5°	6'	-6'
King Pin Angle – RH	9.5°	6'	-6'
Pad RH -12	91mm	0.05mm	-0.05
Pad RH -34	91mm	0.05mm	-0.05
Pad RH -23	98mm	0.2mm	-0.2
Pad RH -14	98mm	0.2mm	-0.2
Pad LH -12	91mm	0.05mm	-0.05
Pad LH -34	91mm	0.05mm	-0.05
Pad LH -23	98mm	0.2mm	-0.2
Pad LH -14	98mm	0.2mm	-0.2
Spring saddle centre	825mm	0.8mm	-0.8

*Degree (°)*

*Minute (')*

*Millimeter (mm)*

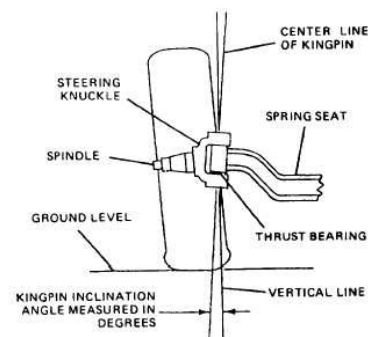
Inspection of the Front Axle Beam is done at each and every station for its quality check. There is no feasibility for a complete inspection of the beam before it goes into the assembly line for final assembly. The company utilizes CMM for inspection and the time taken for inspecting a single beam is 90 seconds. The feature to be inspected are king pin inclination, dimension of pad holes and spring saddle centre (see Table I).

### 3. FIXTURE CONCEPTUALIZATION AND METHODOLOGY OF INSPECTION

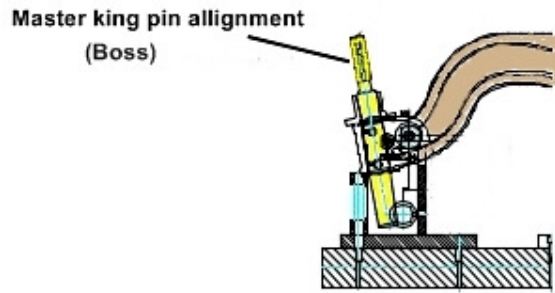
#### 3.1 King Pin inclination

The King Pin is set at an angle relative to the true vertical line, as viewed from the front or back of the vehicle. This is the King Pin inclination or KPI (also called steering axis inclination, or SAI) as shown in Fig.3. SAI is non-adjustable, since it would change only if the wheel spindle or steering knuckles are bent.

King Pin Inclination Angle depends on customer requirement and in this case the angle is equal to  $9^{\circ} 30' (9.5 \text{ Degrees}) \pm 6'$ .



**Fig. 3. King pin inclination**



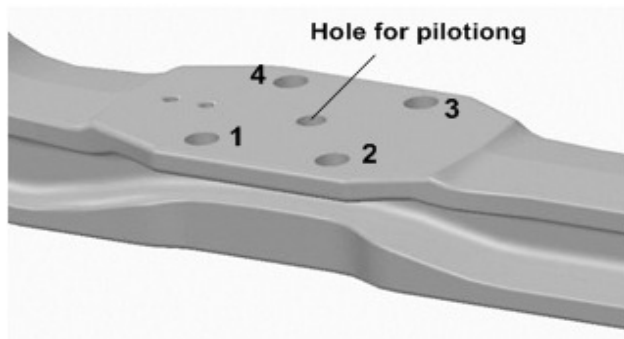
**Fig. 4. Master king pin alignment for inclination inspection**

### 3.2 Pad Holes

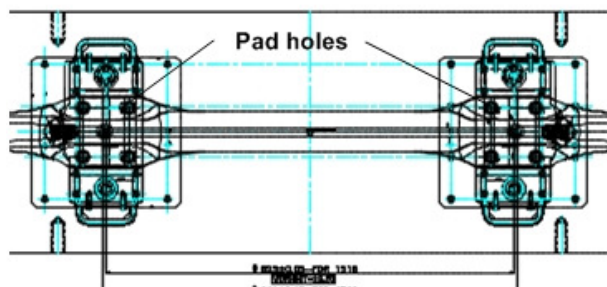
The drilled pad holes are in rectangular orientation on either sides (i.e right and left end) of the beam. These are machined for assembling of the axle on the chassis of the automobile along with leaf springs. This section of beam with pad holes is typically called as spring seat. The distance between them has to be maintained accurately for a precise assembly of the vehicle. There are four number of pad holes at each end of the beam as shown in Figs. 5~6.

The distance between 1 & 2 is  $91\text{mm} \pm 0.05\text{mm}$

The distance between 2 & 3 is  $98\text{mm} \pm 0.2\text{mm}$

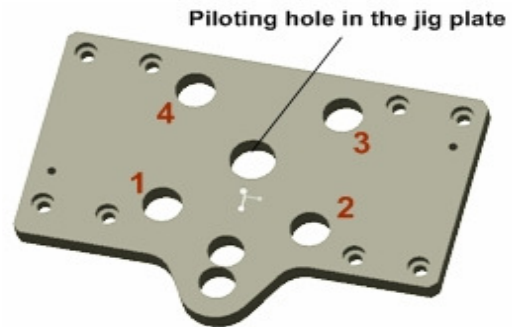


**Fig. 5. Pad holes and Piloting holes on spring seater**

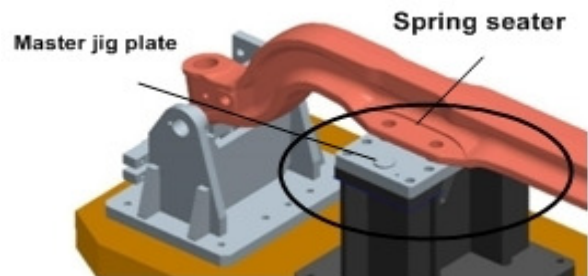


**Fig. 6. 2-D drawing of pad holes on both the ends of the front axle beam**

The holes are located with the help of a master jig plate as shown in Fig.7. The spring seater of the beam is to be rested on the master jig plate as shown in Fig. 8. The location of the holes are inspected with diamond pin locators. The diameter of the pad holes are checked by using GO and NOGO gauges.



**Fig. 7. Master Jig plate**



**Fig. 8. Location of spring seater on master jig plate**

Diameter of Pad Holes

(8 numbers)	= 21 mm
Lower Limit	= 21.00 mm
Upper Limit	= 21.13 mm
Tolerance	= 21.13 – 21.00
	= 0.13 mm

The tolerance of the hole is greater than 0.09 mm. Hence gauge tolerance of 10% is to be provided (Donalson, 1977).

Gauge Tolerance	= 10 % of Work Tolerance
	= 10 % of 0.13
	= 0.013 mm
Wear Allowance	= 5 % of Work Tolerance
	= 0.0065 mm

Therefore,

Nominal Size of

$$\text{GO Gauge} = 21.00 + 0.013 + 0.0065 = 21.0195 \text{ mm}$$

Nominal Size of

$$\text{NO GO Gauge} = 21.13 + 0.013 + 0.0065 = 21.1495$$

Dimension of GO Plug Gauge	=	$21.0195^{+0.013}_{-0.000}$
Dimension of NO GO Plug Gauge	=	$21.1495^{+0.013}_{-0.000}$

### 3.3 Spring saddle centre

The Spring Saddle Centre distance is the length between the two pilot holes on which the Leaf Spring is assembled to the axle. It is measured with the same set up which is used for inspecting the pad holes. This is done by locating the piloting hole in the master jig (Fig.7) and piloting hole in the spring seater (Fig.10) with a piloting pin. The 2-D drawing for the thespring saddle distance inspection is shown in Fig. 9.

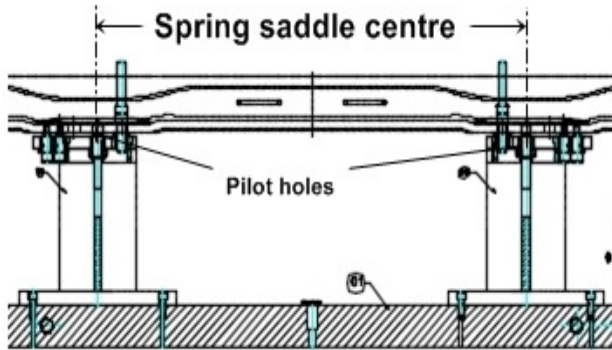


Fig. 9. 2-D drawing for spring saddle centre

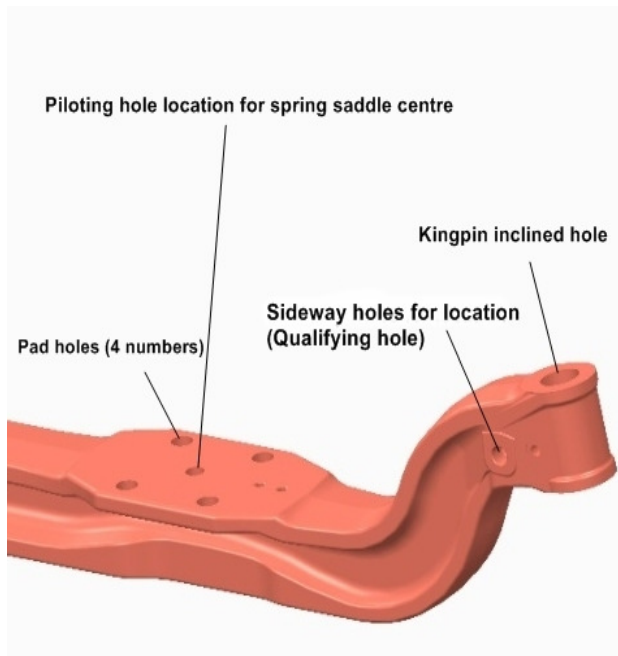


Fig. 10. Representation of pad holes, piloting holes, Sideway hole and inclined king pin hole

### Locating, Resting and Clamping

The beam has two sideways holes called as qualifying holes at both the ends which are especially used for locating the beam (see Fig. 10). So, Inspection fixture is preferred to take the same location holes for inspection.

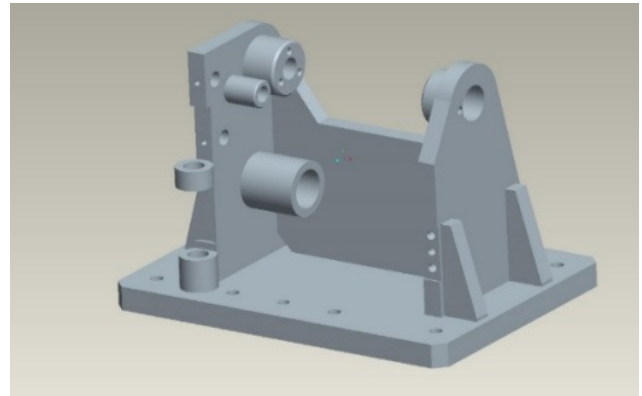


Fig. 11. Left and right end bracket

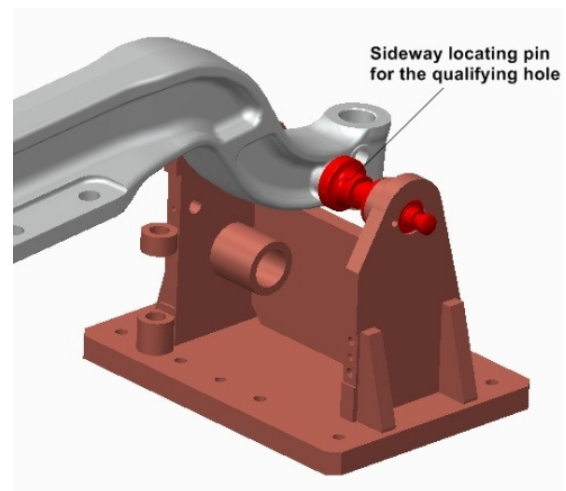


Fig. 12. Side way location in the qualifying hole

The resting and clamping is done by end brackets as shown in Fig.11. Resting of the beam in the inspection fixture is selected on the face of qualifying holes, the location is done by a locating pin as shown in Fig.12. Clamping of the beam in the inspection fixture is selected against the face of qualifying holes as followed for inspection as shown in Fig.13. The 3-D assembly of the fixture is shown in Fig.14.

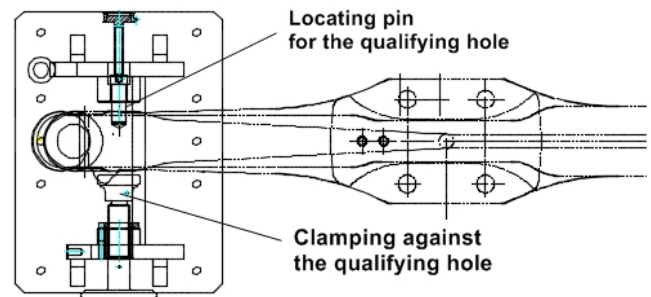
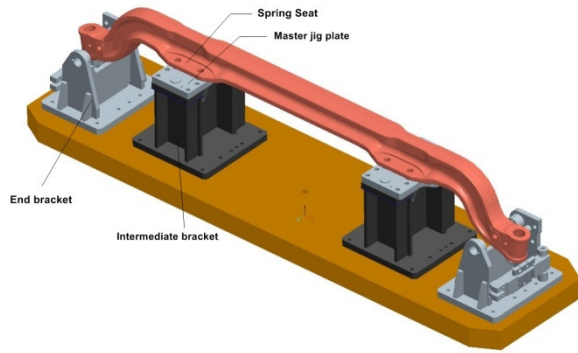


Fig. 13. 2-D drawing for location in qualifying hole and sideways clamping



**Fig. 14. Conceptualization of inspection fixture assembly**

#### 4. SEQUENCE OF INSPECTION

**Sequence 1:** The beam has to be located on the fixture carefully in the qualifying hole on any of the side of the beam and left for gravity to touch the bosses at the bottom of the bracket. A schematic arrangement of master king pin alignment is shown in Fig.4. The location of the qualifying hole is done by locating pin as shown in Fig.12. Upon proper settling of the bosses inside the inclined King Pin hole at both the sides, it is suggested that the king pin hole inclination is right for the forged beam.

**Sequence 2:** Master jig plates are provided to inspect the location of the pad holes in the spring seat. These plates are accommodated on intermediate bracket as shown in Fig.14. The inspection location of the pad holes is done by virtue of diamond pin locators. The diameter of the pad holes are checked by GO and NOGO gauges which are designed in section 3.2. With the same set up, the spring saddle centres are inspected by piloting pin at the centre of the spring seat and jig plate as shown in Fig.7 and Fig.10. Upon proper seating of the pad holes on diamond pin locator and piloting hole in the piloting pin, it is suggested that the location of pad holes and spring saddle centre is correct.

**Sequence 3:** The beam is located and clamped sideways against the qualifying hole with the help of locating pin and sideways clamps respectively provided in the right and left end brackets. A typical set up for arrangement of end brackets and intermediate brackets is shown in Figs.11~12.

#### 5. RESULT AND DISCUSSION

The inspection fixture is manufactured using STARRAG

WMW 500 CNC machine. Standard locating pins are used having 5 micron accuracy. Upon assembly and testing it is found out that the cycle time for inspecting single beam is 45 seconds. In earlier method of inspection using CMM, the cycle time was 90 seconds per beam.

Reduction in cycle time = 45 seconds per beam.

Percentage reduction in cycle time for inspection of single beam = 50 %

#### 6. CONCLUSION

The conceptualization of the inspection fixture is done using CATIA V5. It is made sure that the manufacturing of the same is feasible and to accommodate the same standard pins are used for repeatability. The GO and NOGO gauges are designed for inspecting the pad holes, the dimension of same are  $21.0195^{+0.013}_{-0.000}$  and  $21.1495^{+0.013}_{-0.000}$  respectively. The master jig plate and the right hand and left hand brackets are manufactured with accuracy as close as 5 microns using STARRAG WMW 500 CNC machine, the accuracy of the mentioned CNC machine is 2 microns. A significant reduction of 45 seconds per beam in cycle time is achieved with the inspection fixture resulting in increase in productivity.

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# Weight Reduction of Tractor's Trolley Axle by Suitable Material Selection

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**Abstract:** In India, Tractor's trolley or trailers are very popular and cheaper mode of goods transports in rural as well as urban area. These trailers are manufactured in small scale to moderate scale industries. Such these small scale or moderate scale industries used crude methodologies for designing and manufacturing of the tractor's trolley or trailers. Most of the tractor's trolley used rectangular axle which leads to increase the weight of the trolley and axle. In this study, the existing axle was developed by solid modelling tool and it is modified by changing the cross section of existing axle with suitable material selection. The material selection method as Material Performance Indices (MPI) is used for the selection of the material of modified axle. Based on the finite element analysis, further static analysis is done by finite element analysis tool to determine the von-mises stress, equivalent strain and total deformation. Finally, the result of existing axle is to be compared with modified axle which reduces the weight of the axle, total deformation and also leads to reduce the cost of the axle.

**Keywords:** Weight reduction, Material performance Indices, FEA tool.

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## 1. INTRODUCTION

In the present market scenario, cost reduction technique is playing significant role to meet the competition in the market. Weight reduction and simplicity in design are application of industrial engineering. Various components or products, such as, farming machinery, thrashers, tractor's trolley, etc., mostly used in rural areas are manufactured in small scale industries. It has been observed that these products may not properly design. These products are manufactured as per need, by trial and error methods of manufacturing. So these products are required to design properly. Farm tractor is an off road vehicle, used as a portable machine to do various useful works such as farming, haulage, heavy earthmoving and transportation. An off-road vehicle is considered to be any type of vehicle which is capable of driving on and off paved or gravel surface. Off road condition includes uneven agricultural field surfaces and bumpy village roads on which the tractor has to operate. These ground irregularities leads to unexpected loads coming on the tractor components. The axle of a tractor trolley is one of the major and very important components and needs to be designed carefully, since this part also experiences the worst load condition such as static and dynamic loads due to irregularities of road, mostly during its travel on off road. Therefore it must be resistant to tolerate additional stress and loads.

Trolley axle under consideration is a supporting shaft on which a wheel revolves. The axle is fixed to the wheels, fixed to its surroundings and a bearing sits inside the hub with which a wheel revolves around the axle. A trolley axle

is also called as beam axle which is typically suspended by leaf springs.

## 2. LITERATURE REVIEW

The combination of hollow square shaft is of 90 mm X 90 mm with solid square shaft 75 mm X 75 mm having length 1300 mm which reduces the 22.85% weight as compare to the existing axle without compromising with existing hub assembly of wheel, factor of safety and stiffness of the axle (Katore and Jaju, 2011). The rectangular cross section with circular section by considering the material SAE 1020 (Manasa, Vijaya and Reddy, 2013). The finite element analysis approach is used to modify existing rear axle of hot rolled square section of low carbon steel of cross section 75x75mm & length 1700mm, machined at both ends for fitment of hubs and the elemental analysis of materials(SAE1020) is done on spectrometer (Aloni and Khedkar, 2012).Ductile iron ASTM A536 with grade 65-45-12 was utilized for this process. By redesigning of the axle transition area and change of material which may be a good alternative to enhance the fatigue life with increasing weight to strength ratio and can satisfy minimum design criteria.

Asi (2006) has been carried out the failure analysis of a rear axle shaft used in automobile with the help of a scanning electron microscope equipped with EDX facility and spectrum analysis and micro-hardness measurement revealed that the failed axle shaft material was AISI 4140 steel as hardened and tempered condition and Fractographic features indicated that fatigue was the main cause of failure of the axle shaft. The study of stress generated in the component and then after optimization of its shape and



according to the shape its weight will 10.35% lighter and has more strength than initial design (Dewangan, Pandey and Yadav, 2014).

In this study the fatigue failures are generally of the torsional, rotating-bending, material composition selection etc. and this could be minimize with the help of Taguchi Parametric Optimization Technique (Sharma, Kotiya and Kumar, 2014). The existing axle is a combination of hollow and square shaft of material SAE1045 is replaced by a solid square shaft of dimensions 40mm * 80mm which reduce the weight of 11.5% and cast also. The problem in JD 955 combine manufactured by Iran Combine Harvester Manufacturing Company and workout based on finite element analysis, redesign of front axle was carried out for increasing mechanical strength, easy manufacturability and cost reduction (Khanali et al., 2010). The static analysis and model analysis was carried out for the rear axle housing for two different material as cast iron and mild steel and find out that the design of cast iron is better for manufacturing of rear axle housing (Babu, Amar and Rao, 2011).

### 3. METHODOLOGY

In this study, finite element analysis and Material Performance Indices method was used for the stress

analysis and weight reduction of tractor trolley's axle.

#### 3.1 Static Load Analysis

The trolley chassis main frame is supported at two points over the axle. The chassis is connected to wheel axle through isolator leaf spring and to the tractor coupling. The leaf spring attached to main frame and to the axle at two points and this leaf spring transfer the total load to the axle. The load diagram consists of the total load of load model and weight of axle (Fig. 1).

The specification of 6-tonne 2-wheeler trolley (Table I). The total capacity of the trolley is 60 KN but self weight of trolley and the axle assembly is 13 KN. So we consider the gross weight come over the axle is 73 KN.

From load diagram,  $R_A$  and  $R_B$  show the supports or reactions provided by the tires of trolley. Load 75 kg i.e. 750 N shows the self weight of axle and (3650+3650)=7300 kg i.e. 73000 N is load of goods on trolley for which it is designed and this load is divided equally as point loads and acting on the axle as shown above in the load diagram. Here, to consider upward load as positive sign and downward load as negative sign. The values of reactions, shear force and bending moment are as following (Table II).

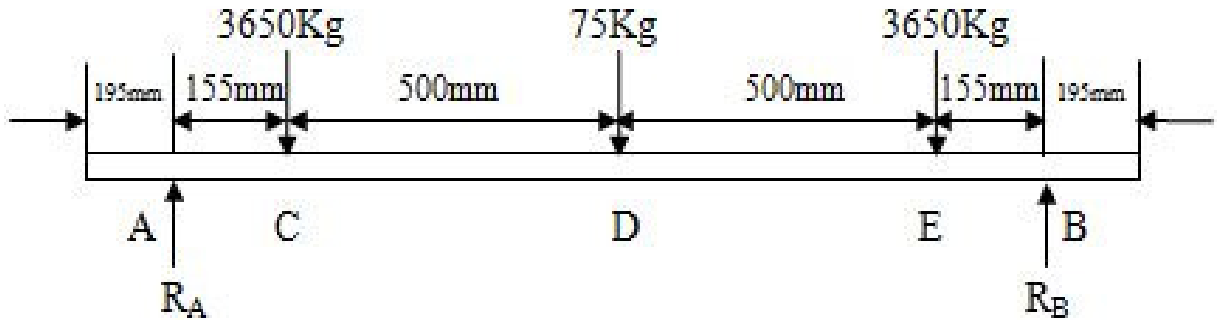


Fig. 1. Load diagram []

TABLE 1: Specification of 6-tonne 2-wheeler trolley [7]

General	Overall Dimensions	Load Capacity	Axle	Tires
Single axle	Chassis Length: 4025 mm.	Pay load: 60 KN	Square section of 75mm x75mm	Width: 9"
	Trolley box Length, Width & Height are 3100mm, 1900 mm & 730 mm.	Unloaded Weight: 13 KN	& Length: 1700 mm	Radius: 20"
	Ground distance: 1700 mm		Square section of 75mm x75mm	
	Chassis Length: 4025 mm.			

**TABLE 2: Values of reactions, shear force and bending moment**

Load point	$R_A = 36.875 \text{ KN}$ Shear Force	$R_B = 36.875 \text{ KN}$ Bending Moment
A	36.875 KN	0 KN-mm
C	0.375 KN	5715.625 KN-mm
D	-0.375 KN	5903.125 KN-mm
E	-36.875 KN	5715.625 = KN-mm
B	0 KN	0 KN-mm

### 3.2 Material Selection Method

Materials science and engineering plays a vital role in this modern age of science and technology. Various kinds of materials are used in industry, housing, agriculture, transportation, etc. to meet the plant and individual requirements.

In this work, one of the methods for material selection as Materials Performance Indices is used for the modified axle. Here, the axle is subjected to bending moment. The objective function is to minimize the mass (m) of the axle.

The mass of the axle = volume  $\times$  density

The volume of axle  $= \frac{\pi}{4} d^2 \times l$

$$\frac{M_b}{I} = \frac{\sigma}{Y_{\max}} \quad (i)$$

$I$  = Moment of inertia

By referring the equation [Eq. (i)],  $\frac{M_b}{\sigma} = \frac{\pi}{32} d^3$  (ii)

So that,  $d = \left( \frac{32 \times M_b}{\sigma \times \pi} \right)^{1/3}$  (iii)

This is substituted in equation of mass, so mass (m)  $= 2.5198 \times \sqrt[3]{\pi M_b^{2/3}} l \times \frac{\rho}{\sigma^{2/3}}$  (iv)

So that, The Material Performance Index (Mi)  $= \frac{\sigma^{2/3}}{\rho}$  (v)

The various material used in existing axle and proposed axle with Material Performance Index (Table III).

**TABLE 3: Material properties with Performance Index**

Material	Ultimate strength(Mpa)	Yield strength (Mpa)	Density (Kg/m3)	Modulus of elasticity(Mpa)	Passion ratio	Mi
SAE1020	420	370	7870	205000	0.29	5.818
SAE 1045	565	310	7872	201000	0.29	6.548
SAE1040(proposed material)	595	515	7845	200000	0.31	8.18

From the above (Table III), SAE 1040 has a highest Material Performance Index so that SAE 1040 is to be selected for the modified axle design which minimized the mass of the axle.

### 3.3 Design of Existing Axle

The axles are used to transmit bending moment only. Thus axles are designed on the basis of bending moment only. The calculation of existing axle design is to be following way.

Total volume = volume of rectangular portion + volume of circular portion

Total volume = (Area  $\times$  length) +  $(2 \times \frac{\pi}{4} d^2 \times l) = (75^2 \times 1310) + (2 \times \frac{\pi}{4} 75^2 \times 195)$  (vi)

Total volume = 8295323.482 mm³ = 0.00829532348 m³

Now, Mass = volume  $\times$  density = 0.00829532348  $\times$  7870 = 65.28 Kg

Now, we will find out the bending stress induced in the existing axle due to the maximum bending moment which is to calculate (Table II)

The bending equation is to be following:

$$\frac{M_{\max}}{I} = \frac{\sigma}{Y_{\max}}$$

The moment of inertia  $I = \frac{bd^3}{12} = \frac{75 \times 75^3}{12} = 2636718.75 \text{ mm}^4$   
(For rectangular portion)

Therefore from bending equation  $\frac{5903125}{2636718.75} = \frac{\sigma}{37.5}$

$\sigma = 83.95 \frac{\text{KN}}{\text{mm}^2} = 83.95 \text{ Mpa} < 370 \text{ Mpa}$ .

Hence the design of existing axle is safe.

### 3.4 Design of Proposed Axle

In proposed axle design, there is circular cross section of 75 mm diameter, 1310 mm long solid shaft Further this solid shaft extends at both with 55 mm diameter & 195 mm length.

Total volume = volume of 75 mm diameter + volume of 55 mm diameter

Total volume =  $(\frac{\pi}{4} d^2 \times l)$  75 mm diameter +  $(2 \times \frac{\pi}{4} d^2 \times l)$  55 mm diameter

$= (\frac{\pi}{4} 75^2 \times 1310) + (2 \times \frac{\pi}{4} 55^2 \times 195) = 0.0067139762 \text{ m}^3$

Now, mass of the axle (m) = volume  $\times$  density =  $0.0067139762 \times 7845 = 52.67 \text{ Kg}$

Now, we will find out the bending stress induced in the existing axle due to the maximum bending moment which is to calculate (Table II)

The bending equation is to be following:

$$\frac{M_{\max}}{I} = \frac{\sigma}{Y_{\max}}$$

The moment of inertia  $I = \frac{\pi}{64} \times d^4 = \frac{\pi}{64} \times 75^4 = 1553155.548 \text{ mm}^4$

From bending equation  $\frac{5903125}{1553155.548} = \frac{\sigma}{37.5}$

$\sigma = 142 \text{ Mpa} < 515 \text{ Mpa}$

Hence, the design of modified axle is safe and weight is reduced from 65.30 kg to 52.67 kg.

## 4. RESULT

The stress analysis of above existing axle as well as proposed axle is done by using FEA tool. The results from FEA are equivalent stress (Von-mises) and the total deformation.

### 4.1 Analysis of Existing Axle

Axle was created in solid modeling tool and then the analysis was carried using the finite element tools for the von- mises stress and total deformation.

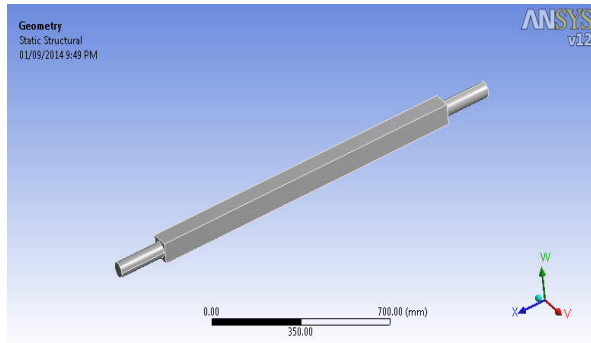


Fig. 2. Solid geometry of existing axle

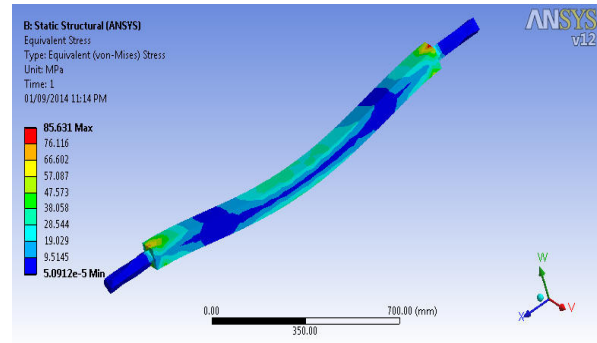


Fig. 3. Von-mises stress (SAE 1020) in existing axle

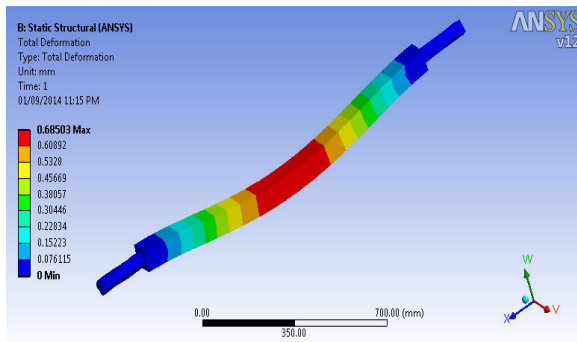


Fig. 4. Total deformation (SAE 1020) in existing axle

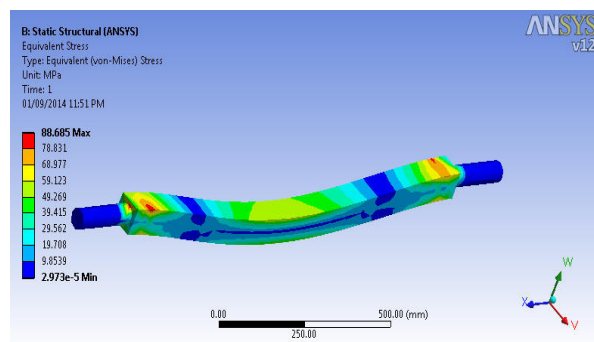
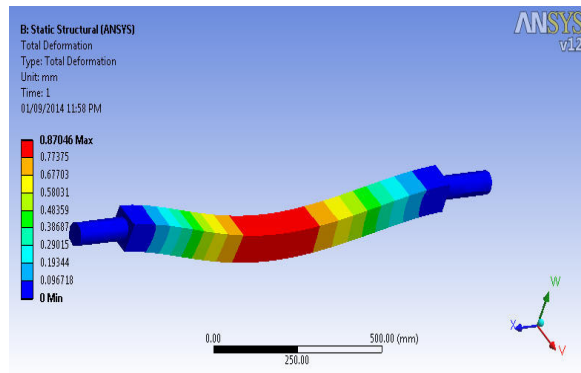


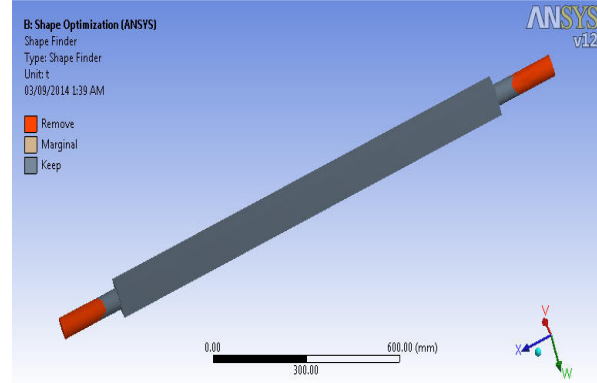
Fig. 5. Von-mises stress (SAE 1045) in existing axle





**Fig. 6. Total deformation (SAE 1045) in existing axle**

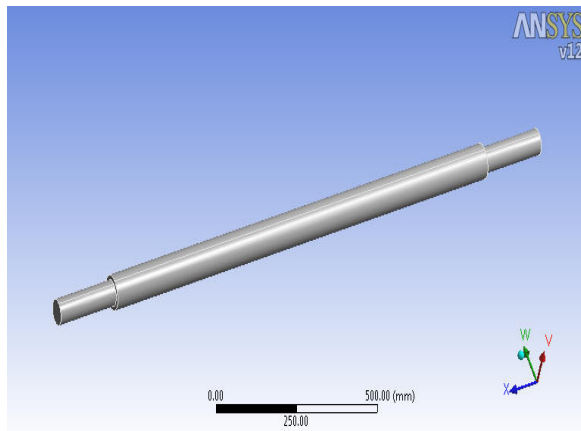
From referring the figures (Figs. 2~6), the von-mises stress and the total deformation of materials SAE 1020 and SAE 1045 was carried out using FEA tool. The shape optimization of existing axle was carried out in FEA tool and there is only change at the both ends of the axle which is not possible so that the cross section of the existing axle is to be change by changing the material.



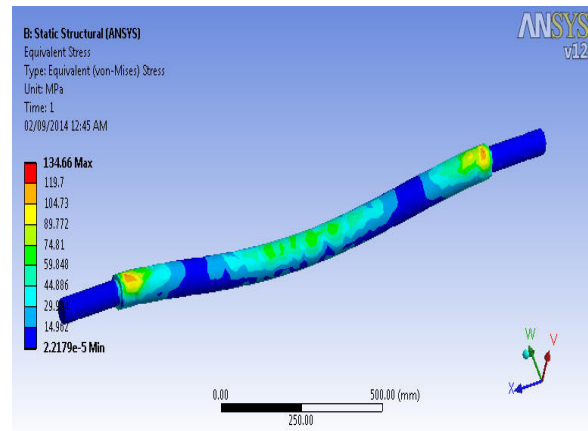
**Fig. 7. Shape optimization of existing axle**

#### 4.2 Analysis of Proposed Axle

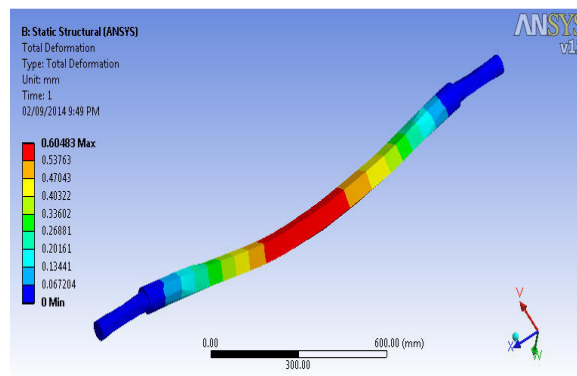
After the analysis of existing axle with existing material of SAE 1020 and SAE 1045, the rectangular cross section was replaced by circular cross section. The analysis of proposed axle with proposed material of SAE 1040 was carried out using FEA tool.



**Fig. 8. Solid geometry of proposed axle**



**Fig. 9. Von-mises stress (SAE 1040) in proposed axle**



**Fig. 10. Total deformation (SAE 1040) in proposed axle**

The propose axle is analyzed by using the same boundary condition as well as loading condition. The material selected for the proposed axle is SAE 1040 which is ideal for the shaft, axle and other machine pars requiring better strength than SAE 1020 and SAE 1045 which is used in the existing axle. Here, the red color shows the maximum values of stress, equivalent strain and total deformation and blue color shows the minimum values of stress, equivalent strain and total deformation. The stress produced in the proposed axle is within a permissible limit so that the design of the proposed axle is safe under the loading condition.

#### 4.3 Comparison between existing axle and proposed axle

**TABLE 4: Comparison between existing axle and proposed axle**

	Existing axle		Proposed axle
Material	SAE 1045	SAE 1020	SAE 1040
Minimum section modulus	70.30×103 mm ³	70.30×103 mm ³	41.57×103 mm ³
Von-mises stress	88.685 Mpa	85.631 Mpa	134.66 Mpa
Total deformation	0.87046 mm	0.68503 mm	0.60483 mm
Total weight	65.30 Kg	65.07 Kg	52.67 Kg

#### 5. CONCLUSION

The existing axle used in tractor's trolley has a heavy cross section modulus as 70.30×103 mm³ and more total deformation of the axle. Most of the material used in the existing axle are SAE 1020 & SAE 1045 with 75 × 75 mm rectangular axle and the weight of the axle 65 Kg. In proposed axle design of circular cross section with material SAE 1040, the weight as well as the total deformation is reduced compare to the existing axle.

In this study, also material selection method as Material performance Indices is to be used for the selection of the material which has a highest Performance Index. By using this method, a material SAE 1040 has a highest Performance Index as 8.18 so that this material is to be used for the proposed axle design. The proposed axle design as 75 mm of circular cross section with section modulus 41.57×103 mm³ is to be reduced the weight by 19.34% and

also reduced the total deformation from 0.68503 mm to .60483 mm. The stress develop in proposed axle is 134.66 Mpa which is in the permissible limit so that the proposed axle design is under safe condition.

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# Hydarulic Fixture – Modern Day Technology to Improve Productivity – A Review

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**Abstract:** A revolutionary change has taken place in the field of fluid power technology due to the integration of electronics as a control medium for hydraulic components and systems. Due to increased sophistication of hydraulics and allied fields of engineering, the hydraulically driven machines are now able to generate more power and higher accuracy in speed, force and position control. But its application in Indian industries is of comparatively recent choice and hence, there is a great deal of urgency and importance to master the art of its application and maintenance. Application of hydraulic systems till now was limited to machine tools, material handling devices, transport and other mobile equipment, in aviations systems, etc. but very few applications and research work is carried out on hydraulic fixture. This paper reports review, practices and future directions of hydraulic fixture as a means to improve productivity.

**Keywords:** Hydraulic, Fixture, Clamping, Productivity

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## 1. INTRODUCTION

If a component is to be produced in a small numbers, then procedure adopted is marking out, setting on machine, clamping to machine table. But it would not be suitable for producing same component in large quantities because of economic reasons. A faster and more profitable method calls for a device on which components can be quickly positioned in the correct relationship to the cutting tool and quickly clamped for machining. Fixtures are designed to hold, support, and locate every part to ensure that part is machined within the specified limits.

Manufacturing industries have brought lot of revolutions in manufacturing technology, as a consequence of which several developments like CNC lathes, CNC machine centre, flexible manufacturing systems, fabrication centre, transfer machines, robotics etc. took place. Even with these advancements in the manufacturing industries, there is a continued use of jigs and fixtures in some form or the other either independently or in combination with other systems.

The machine tool industry has undergone sufficient changes as the requirement of user engineering systems changed; first it started with the manufacture of basic general purpose machine tools. These machines though offered higher flexibility were not suitable for mass production owing to longer set up times and the tedious adjustments of machine and tools besides requiring highly skilled operators. With growing need of fast production to meet the requirement of industry, mass production machines are conceived. Hydraulic, tracer control machine tool, special purpose automatic and semi automatic machines were introduced with the advancement of technology. These machines were highly specialized but inflexible. The use of these machines

was with a success for mass production and they have considerably reduced the production costs by way of reduced machining times and labor costs. Because of inflexibility these machine tools could not however be adopted by units involved in small lot and piece production.

Because of the above, great need is felt for tools that could bridge the gap between highly flexible general purpose machine tools (which are not economical for mass production) and highly specialized, but inflexible mass production machines. Fixture has taken up this role very well.

Outcome of fixtures is limited by clamping errors in workpiece positioning. Key aspect is work holding during machining process and fixtures are the elements responsible to satisfy this general goal. Localized elastic deformation of the workpiece caused by clamping forces at the fixturing points significantly influence workpiece location in a fixture. An urge to solve these problems has excited this research on hydraulic fixture – a modern day technology. Various methods to avoid problems due to clamping forces like combining locator and clamp in a single component, active clamping, sensory system, strain gauge etc. are proposed by various renowned authors, but use of hydraulic fixture was not conceptualized. This paper proposes an innovative approach of use of hydraulic fixture, which reduces fatigue of the operator and proves an excellent method to improve productivity.

## 2. USE OF HYDRAULICS IN FIXTURING

The basic requirement of a fixture is to locate and secure the workpiece in the correct orientation and relationship so the manufacturing process can be carried out according to design specifications (Nee and Kumar 1991). A typical

fixture for prismatic parts consists of three components: locators, clamps, and supporters. Locators are used to position the workpiece in static equilibrium thus removing all degrees of freedom. Clamps are for holding the workpiece firmly against the locators during machining for rigidity. The external cutting forces and tool direction are the major considerations. Additional support is added to reinforce the stability of the workpiece. The use of these fixturing elements can be determined manually or analytically. Since the workpiece is subjected to the external cutting forces of machining, the three above fixture elements must make sure that the workpiece is positively located, is rigid, and assures repeatability. Repeatability refers to the workpiece and subsequent workpieces can be located by the fixture in precisely the same place. This activity is considered a 'set-up' in manufacturing.

To make sure that the workpiece maintains the dimensional specifications and tolerances, the external cutting forces must be resisted by the fixture so that the workpiece remains in equilibrium. The workpiece has unconstrained spatial motion of 12 degrees of freedom in 3D space. These movements are along the positive and negative directions of the x, y and z axes and clockwise and counter clockwise rotations about the three axes. The degrees of freedom are constrained by the locators and clamps.

Centering, locating, orientating, clamping, and supporting, can be considered the functional requirements of fixtures, 'what a fixture must do independently of any particular solution'. In terms of constraints, 'what limits the range of possible solutions', there are many factors to be considered, mainly dealing with: shape and dimensions of the part to be machined, tolerances, sequence of operations, machining strategies, cutting forces, number of set-ups, set-up times, volume of material to be removed, batch size, production rate, machine morphology, machine capacity, cost, etc. At the end, the solution can be characterized by its: simplicity, rigidity, accuracy, reliability, and economy.

The deformations caused by the clamping in the fixture are normally associated to existing distortion in the raw workpiece due to previous manufacturing processes and to the clamping forces as stated by Oscar Gonzalo et al. (2017). These problems lead to uncertainties in the set-up process, hindering the fixture functions, the achievement of a right positioning of the workpiece and the avoidance of deformations due to clamping forces. Hydraulic clamping elements in fixturing can reduce harsh environment for the workpieces. Following are the advantages of use of hydraulics for clamping.

### **2.1 Advantage of Hydraulic in Clamping**

#### **i. Saves Time**

Manual clamping and declamping requires 15 to 20 seconds per clamp. For a fixture with multiple clamping points, the

total time for clamping will be more than one minute. For uniform clamping, this time will be still more. This time can be saved by automatic clamping. The pay back period for the cost of automation can be estimated considering the net saving per job. (Time saved x Machine hour rate). Advantage of time saving is increase in production capacity of bottle neck machines.

#### **ii. Reduces operator fatigue**

In manual clamping, the efficiency of the operator decreases due to fatigue. This may result in less clamping torque at the end of the shift, specifically for the elderly operators, causing reduction in safety. A humane approach is more important than the clamping efficiency. By introducing automatic clamping system, one operator can handle two or more machines simultaneously.

#### **iii. Improves quality of clamping**

Only one point can be clamped at a time during manual clamping. To achieve uniform clamping, initially all the bolts are clamped with a light clamping force and then with a heavy clamping force. Clamping force at each bolt may vary. However with automation –

- All clamps can be operated at the same time. There is no need of a light and heavy clamping force.
- Clamping force can be controlled as per the requirement, to control dimensional accuracy.
- Clamping force is consistent.

### **3. HYDRAULIC FIXTURE CONSIDERATIONS**

As stated by Koji Teramoto, Masahiko Anasoto and Kazuaki Iwata, Fixturing Plan (FP) and Machining Plan (MP) are mutually dependent. The design of machining fixtures relies on designer experience and his/her implicit knowledge to achieve a good design. In order to facilitate its application, the explicit definition of the fixture design process and the knowledge involved is a prior and a fundamental task to undertake.

Additionally, a fundamental and well-known engineering principle should be considered: the functional requirements and their associated constraints should be the first input to any design process. A relevant issue when considering requirements, taking this as a general concept, is to make explicit the meaning of two main terms: Functional Requirement (FR) and Constraint (C).

Functional Requirement (FR), as it stated by different authors, 'represents what the product has to or must do independently of any possible solution'. Constraint (C) can be defined as 'a restriction that in general affects some kind of requirement, and it limits the range of possible solutions while satisfying the requirements'.

Usually, a fixture solution is made of one or several physical elements, as a whole the designed fixture solution must satisfy the entire FRs and the associated Cs. Centering, locating, orientating, clamping and supporting, can be considered the functional requirements of fixtures. In terms of constraints, there are many factors to be considered, mainly dealing with: shape and dimensions of the part to be machined, tolerances, sequence of operations, machining strategies, cutting forces, number of setups, set-up times, volume of material to be removed, batch size, production rate, machine morphology, machine capacity, cost, etc.

At the end, the solution can be characterized by its: simplicity, rigidity, accuracy, reliability, and economy. The methodology proposed for design of a fixture includes the realization of two stages. The first stage represents the knowledge of the objects like part geometry, machining process, functional and detailed fixture design, and fixture resources. The second stage describes the inference process (design and interpretation rules) needed to obtain a first solution for the machining fixture .

Low stiffness of the components affect the manufacturing processes, which limit the quality and precision of the final product. In the machining process, precision is one of the most important issue resulting in rejection is the part static deformation and the dynamic vibrations. The static deformation is mainly affected by two factors: deformation due to clamping and process forces affect the static deformation, and geometrical distortions due to material removal and residual stress relieving during processing.

The deformations caused by the clamping in the fixture are normally associated to existing distortion in the raw workpiece due to previous manufacturing processes and to the clamping forces. These problems lead to uncertainties in the set-up process, hindering the fixture functions, the achievement of a right positioning of the workpiece and the avoidance of deformations due to clamping forces.

Oscar Gonzalo et al. (2017) presented an analysis to identify the causes of the static deformations during clamping and a method to correct the geometrical distortion and deformation of a clamped workpiece by the evaluation of the reaction forces in the selected relevant clamping points. It covers the design and validation of an active clamping unit to minimize the deformation produced by the fixture that could affect the machining process. The developed clamping unit presents an alternative to combine the locator and the clammer in a single component that controls the reaction force and the deformation of the workpiece in the clamping point, and it performs the positioning of that point to minimize the distortion of the workpiece. The clamping unit was verified in laboratory conditions and then tested in an industrial application, evaluating the capabilities related to positioning and reaction force control.

S. K. Hargrove and A. Kusiak (1994) presented taxonomy of fixture planning and design, in which selection of clamping devices, limited deformation, human factors etc. related to fixture are given importance in most of the phase as shown in Table 1.

**TABLE 1: TAXONOMY OF FIXTURE PLANNING AND DESIGN**

Phase	Requirements	Methods and tools
Planning	Production volume Machine resources Quality standards	Production planning techniques Machine capabilities
Design analysis	Accurate locating of workpiece Total restraint of workpiece during machining Limited deformation of workpiece No machining interference Optimal setup sequence	Tolerance analysis Expert systems, FEA, features CAD/CAM, CAPP Optimization methods Workpiece representation
Synthesis	Select fixture elements for locating Select fixture elements for clamping Select fixture elements for support	Modular fixtures Chucks, centre, collets Comfortable and programmable fixtures, Phase-change NC fixturing systems, etc.
Assembly	Manual assembly Automated assembly	Human factors Robotic technology Man-machine interfaces

*Now follows conclusion.*

#### 4. CONCLUSION

Fixtures are an essential element of the machining system and clamping force is the major consideration while designing and using a fixture. Hydraulic fixture using hydraulics principles for clamping is a modern day technology to decrease non-productive time, reduce operator fatigue and improve productivity. However, an integrated approach of hydraulics principles, hydraulic circuit design, numerical control machine tools, machining programming, sensory system, active clamping, use of strain gauge etc. may result in advantages in manufacturing process, ergonomics, productivity improvement and industrial engineering.

The aim is to develop a hydraulic clamping system, which can be used in mass production with the help of a clamping technology manufacturer and a fixture industry. The design of a fixture is a highly complex and intuitive process, which require knowledge. Fixture design plays an important role at the setup planning phase. Proper fixture design is crucial for developing product quality in different terms of accuracy, surface finish and precision of the machined parts. The fixture set up for component if done manually result in more cycle time loading and unloading the material. So, there is need to develop system which can help in improving productivity and time. Fixtures reduce operation time and increase productivity. The recent trends in industry are towards adopting the hydraulic techniques, because it save time generates accuracy and it is having some flexibility.

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# Anthropometric Study of School Children for Ergonomic Design of School Furniture

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**Abstract:** This paper presents the results of an anthropometric survey conducted on schoolchildren (age 10-16 years) residing in the Solapur region from Maharashtra State, India. A set of 14 anthropometric characteristics was taken based on Indian standards and literature review. The sample consisted of 1845 children (990 boys and 855 girls). The results of statistical analysis indicate that the anthropometry of students vary with age, gender and living standards. One important fact revealed was that there is too much variation in the anthropometric characteristics even within the same age group. Hence it was concluded that it may not be possible to accommodate all the school children with single model of school desk. Comparison with earlier data shows growth of 6% indicating need of conducting periodical surveys. The data were presented in the form useful for the ergonomic design of school furniture as well as other products used by the school children.

**Keywords:** Anthropometry, School furniture, Ergonomic.

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## 1. INTRODUCTION

Efficiency of a person depends strongly on the fact that how comfortable a person is with the work environment and also the suitability of workstation with the user. Therefore it is very important to make the classrooms in schools comfortable and suitable for students, so that they can concentrate and evolve as talented individuals. [Syed Asif 2012] There is no denying the fact that the designs of the classroom furniture being offered in educational establishments in India are not addressing needs of the school children. The provision of ergonomically designed school furniture, based on the anthropometric dimensions of the children, is essential for comfort and prevention of musculoskeletal disorder that may arise from the use of mismatched furniture. [J. M. Rohani et al. 2015]. The prevalence of back pain among high-school learners is high and increases with age; by 15 years of age their lifetime prevalence exceeds 50%. Accepted risk factors for the development of back pain are the design and dimensions of traditional school furniture and the student and furniture mismatch [S. M. V. Niekerk et al. 2013]. Several other research studies [M. K. Gouvali and K. Boudolos 2005], [H. I. Castellucci et al. (2010)] [Murphy et al.] support the findings that the existing classroom furniture is not ergonomically designed and hence contributes in major way to cause back pain and other musculoskeletal disorders prevalent in the school children.

For ergonomic design of the products availability of latest anthropometric data of the users becomes the preliminary step. Changing of climate conditions, developing of socio

and economical conditions and health services, increasing percent of individual education level and changing of their feeding habit cause anthropometric measurements increase over the period. Hence it is necessary to update the anthropometric data every 8-10 years. [Durshan Kaya et al.] Several studies have established the fact that the anthropometric characteristics also change with region and ethnic differences. Hence it becomes necessary to collect the data region wise and periodically. [Joanne W. Y. Chung and Thomas K. S. Wong, (2007)], [S. Anbhan Ariadurai et al. Srilanka (2009)]. In India few studies have been carried out related to this area of ergonomic design of school furniture. From the available studies it is revealed that latest anthropometric data of the school children are not available for different regions. In Maharashtra state where population of school children is more than 15 million, hardly any anthropometric survey has been conducted in last 20 years for the school children. Hence the purpose of this study is to collect the anthropometric data of schoolchildren analyze the same and to present it in useful form to designers and manufacturers of the classroom furniture.

## 2. METHOD

Students from 7 schools located in different locations of the Solapur region 4 from the city and 3 from rural area were identified. Care was taken to see that the schools cover students from different socioeconomic strata of the society in Solapur. Students from the age group of 10 -16 years, studying in 5th to 10th standards are involved. Necessary permissions from the Education officer, School authorities, parents and students are taken before the measurements. 10

students from each division of the different divisions of each standard are randomly selected.

### 2.1 Method and equipment used for Measurement

The body measurements of each student are carried out using standard anthropometric measurement techniques [15]. All anthropometric measures are taken with the subjects wearing regular school uniform and without shoes. The measurements were taken on a chair placed on level floor in one of the classrooms in each of the selected institutions. Students were asked to sit erect with upper and lower legs at 90 degrees to each other. Measurements are taken with the assistance of two teams each consisting of two persons, one for taking measurement and another for recording. To ensure accuracy of recorded data, the persons were given training of using the anthropometer and other measuring devices in the laboratory and trial runs were conducted. The measurements during the trial runs were checked for consistency and accuracy.

Measuring Equipment consists of anthropometer, measuring tape, steel scale, adjustable chair, a platform for measurement of foot length and a weighing scale for measurement of weight. Body dimensions are measured to the accuracy of 1mm.

### 2.2 Measurements

Following body dimensions are measured.

1. Stature (S): Standing height of subject from floor to top of head.
2. Sitting Eye Height (SEyH): Vertical distance from the seat surface to the inner canthus (corner) of the eye.
3. Sitting Shoulder Height (SShH): Height of shoulder from seat top surface.
4. Lower Lumbar (5th) Height (LLH): The vertical distance from the seat surface to 5th lumbar vertebral point.
5. Foot Length (FL): Horizontal distance between toe and heel, measured with foot in flat position on the ground.

6. Knee Height Sitting (KHS): Measured with 90° knee flexion, as the vertical distance from the floor or footrest and the top surface of the knee.
7. Popliteal Height (PH): Height of posterior surface of knee from floor knee flexion 90 degrees.
8. Buttock-Feet Length, Sitting (BFL): It is the maximum distance from the buttock to the acropodion of the children.
9. Buttock-Knee Length (BKL): Horizontal distance from the back of the uncompressed buttock to the front of the kneecap.
10. Buttock-Popliteal Length (BPL): The horizontal distance from the most posterior aspect of the right buttock to the posterior surface of the right knee, subject sitting.
11. Elbow to Fingertip Length (EFL): Distance between elbow to fingertip of middle finger.
12. Shoulder Breadth (bi deltoid) (ShB): Horizontal distance between two shoulders.
13. UAL: The vertical distance measured between acromion (top of the shoulder) and lower end of the elbow.
14. Hip Width (HW): Horizontal distance between two exterior points of hip, subject sitting.

### 3. DATA ANALYSIS RESULTS AND DISCUSSIONS

Measured data were analyzed by SPSS16 software. Initially data cleaning was done and normality tests were conducted. (Shapiro Wilk test  $p > 0.05$ ). Descriptive analysis was done which provide the values of the important statistical parameters such as mean, standard deviation, range, minimum and maximum values, percentile values, etc. Table 3.1 present the percentile data related with all the measured anthropometric variables. This data are very useful for the ergonomic design of the products being used by the children such as, furniture, clothing, sports equipment etc.

**TABLE 3.1: Percentile Data for Anthropometric Variables**

AV	Minimum	Maximum	Percentiles										
			5	10	20	30	40	50	60	70	80	90	95
ST	1111	1827	1275	1314	1369	1411	1445	1475	1511	1541	1584	1641	1687
SEyH	452	788	528	551	575	593	609	623	638	655	675	701	722
SiShH	322	637	392	413	433	449	463	476	491	505	524	547	568
LLH	20	182	55	64	76	85	93	100	108	116	125	136	145
FL	154	285	181	189	198	204	209	215	220	225	232	242	251
KHS	342	564	399	414	428	439	449	459	468	478	490	506	523
PH	300	467	335	345	357	365	372	379	386	393	401	413	425



AV	Minimum	Maximum	Percentiles										
			5	10	20	30	40	50	60	70	80	90	95
BFL	383	813	491	516	553	576	594	613	632	651	670	701	728
BKL	328	651	397	417	440	456	473	487	502	517	535	562	578
BPL	261	567	327	346	371	389	403	416	429	442	458	478	498
EFL	277	504	330	341	357	370	379	388	397	407	420	438	451
ShB	177	443	271	285	299	310	318	328	338	346	358	375	388
HW	145	405	213	225	242	254	264	274	285	296	309	328	344
UAL	138	449	203	224	248	265	278	290	303	316	333	353	373

Similarly, descriptive data analysis is done for all the variables. Table 3.2 presents descriptive data for a sample variable Popliteal Height – PH. This data form useful basis for ergonomic design of school desk.

**TABLE 3.2: Descriptive Data For Anthropometric Variable - PH**

POPLITEAL HEIGHT								
		Mean	Minimum	Maximum	Range	Standard Deviation	Percentile 05	Percentile 95
STD	5	364	296	432	136	24	324	409
	6	370	306	424	118	22	333	407
	7	377	308	437	129	22	340	410
	8	385	324	453	129	23	348	425
	9	390	314	463	149	25	351	433
	10	405	344	490	146	25	363	447
Size 1- Std. 5-7	5-7	370	296	437	141	23	332	409
Size 2- Std. 8-10	8-10	393	314	490	176	25	352	437
All Std. 5-10	5_10	381	296	490	194	27	338	427

Careful examination shows that values of all the variables are increasing with the age. However, interesting fact is that even within the same age group, there is substantial variation in the values of a variable. Hence further analysis is done to find out the percentage variation in case of each variable. The Tables 3.3 depicts the percentage variation for

one sample variables KHS in each standard, as well as by considering fifth to seventh standards as a group of size I, eighth to tenth standard as a second group size II and then for standard fifth to tenth as a third group of size I and II together.

**TABLE 3.3: Percentage Variation in Each Standard for Knee Height Sitting (KHS)**

KHS					
STD	Mean	Minimum	Maximum	Range	Percentage variation
5	431	357	495	138	32%
6	442	375	505	130	29%
7	454	389	523	134	30%
8	471	400	543	143	30%
9	476	405	575	170	36%
10	500	416	586	170	34%
5-7	443	357	523	166	37%
8-10	481	400	586	186	39%
5-10	462	357	586	229	50%

Careful examination of the table indicates that the variations in the values are very high. Overall variation in the entire group from age 10 to 16 is around 50%. This is natural as the values of anthropometric variables go on increasing with age. However, interesting fact is that even for the same standard or age group e.g. for standard V (age group of 10-11), the variation is to the tune of 32%, which is very high. This finding is true for each standard or age

group and moreover for each anthropometric variable.

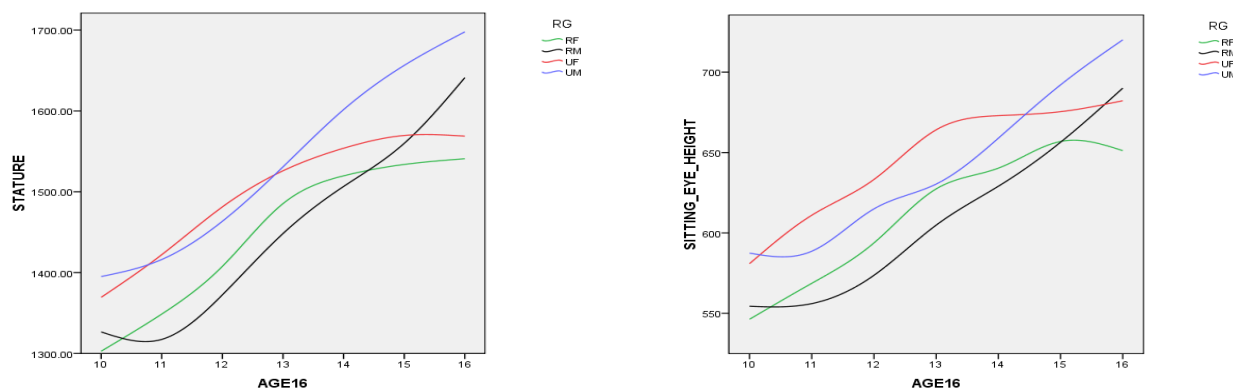
Further analysis was done to study the effect of age, gender and rural and urban living standards. The following table 3.4 shows the variation in stature for these different factors. Similarly, fig.1 displays the graphs showing variation of anthropometry with age and effect of factors like rural / urban living and sex.

**Table 3.4: Effect of Age, Gender and Living Standard on the Anthropometry - Stature**

STANDARD	STATURE							
	FEMALE				MALE			
	RURAL		URBAN		RURAL		URBAN	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
5	1333.70	82.46	1380.85	86.06	1343.74	76.17	1403.55	59.26
6	1386.56	88.42	1434.80	75.09	1331.16	65.20	1415.18	73.76
7	1469.20	84.32	1478.72	84.39	1401.19	72.37	1470.12	82.79
8	1498.65	68.67	1527.40	68.47	1466.54	86.65	1536.25	96.88
9	1541.18	65.08	1550.19	64.57	1513.56	84.89	1601.60	96.44
10	1538.18	60.49	1569.78	69.01	1607.35	87.89	1669.83	95.44

Study of the table 3.4 and fig. 1 reveal the following facts.

- Values of anthropometric variables go on increasing with age for all students of both the genders and residing both in urban and rural regions.
- However, when we compare the growth gender wise, for females there is rapid rise in the values in the earlier age i.e. standard 5-8th and later the rate slows down. While for boys growth rate is relatively less for early age i.e. standard 5-7th and later the rate picks up considerably.



**Fig. 1. Graphs showing effect of Age, Gender and Living Standard on Anthropometry.**

- One more observation is that although growth rates of girls stabilize by the age of 16, for boys still, growth continues at rapid rate even beyond age 16. This fact indicates the difference between the genders reaching puberty.
- At the age of 16 years, values for males are higher than those of females by 5-6% irrespective of living standard. However, final difference could be still higher, considering the fact that, growth rate of boys is still at peak, while for girls it is stabilized.

All these findings are in line with the earlier studies done by B Y Jeong and K S Park, Dr. E. Bardurlu, M D Kaya etc

As stated earlier, for any ergonomic design availability of up to date anthropometric data is an essential requirement. This study aims particularly at ergonomic design of classroom furniture or school desks. In India mainly dual desks are very commonly used in the majority schools [ P V Salunke et al.]. The design parameters of the school desks important from ergonomic aspects have been identified by many authors. However, the study done by P V Salunke et al. considers maximum parameters. In the empirical approach for ergonomic design of school desk, many authors [Claudia Parcelles, Gouvali and Boulodos Castellucci] have established mathematical relationships between the desk parameters and relevant anthropometric variables. The mean as well as percentile values of the anthropometric variables become useful for designing the dimensions of the school desks based on these empirical formulae.

#### 4. CONCLUSIONS

From the data analysis, results and findings following conclusions are drawn. Rise in the anthropometric measures with age (10-16 Years) is substantial (> 50%). Similarly, variation in the anthropometry within the same age group is also significant. Hence a single or two models of the school desks may not be able to accommodate all the students. The ergonomists and designers have to consider that the factors such as gender as well as difference in the rural / urban living standard have cognizable effect on the growth pattern of the children. It is also emphasized that there is need to conduct anthropometric survey periodically. The anthropometric data would be useful for all the people concerned with school children viz. designers and manufacturers of school furniture and other products, ergonomists, consumers etc.

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# Static and Dynamic Comparative Analysis of Small Scale Horizontal Axis Wind Turbine Blade

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**Abstract:** As it is not possible to store the wind and use it at a later time because wind turbines can produce energy only in response to the resource that is immediately available, the output of a wind turbine is thus fluctuating. Therefore, special attention is needed during designing and analysis of wind turbine blade. This paper describes the comparative analysis of different methods used in FEA while designing horizontal axis wind turbine blade. Static structural and dynamic analysis were performed in this research. Theoretical calculations were obtained for natural frequencies by mathematical formulation of the wind turbine blade as Euler-Bernoulli cantilever beam. The blade was checked for two different materials in the analysis. Finally, comparison of the results of dynamic modal analysis were made for both the materials in consideration. From the structural and modal analysis, it is concluded that the blade when modelled with carbon fiber reinforced polymer (CFRP) material, gives better results than that when glass fiber reinforced polymer (GFRP) material is used for the blade.

**Keywords:** Structural, wind turbine blade, Modal analysis, Euler-Bernoulli

## 1. INTRODUCTION

A wind turbine is a machine which converts the power in the wind into electricity. In modern wind turbines, the actual conversion process uses the basic aerodynamic force of lift to produce a net positive torque on a rotating shaft, resulting first in the production of mechanical power and then in its transformation to electricity in a generator. Today, the most common design of wind turbine type is the horizontal axis wind turbine, the axis of rotation of this turbine is parallel to the ground. The major aspects of wind turbine performance are determined by the aerodynamic forces generated by the mean wind. Dynamic forces of the wind can be understood only when aerodynamics of steady state operation of the turbine is understood. Once the basic layout of the turbine is selected, the next step in the design process is to consider in detail the loads that the turbine must be able to withstand.

As is commonly used in mechanics, the loads are the externally applied forces or moments to the entire turbine or to any of the components considered separately (Manwell, McGowan and Rogers, 2009). Erick et al (2014) were manufactured wind turbine blades for 600W turbine for environmental conditions of coast of Michoacán, Mexico based on BEM theory. Supeni et al (2012) addresses the adverse structural response of the blade profile with the variation of operational parameters such as wind velocity and material properties on blade's performances. Maximum stress in the spherical rotor is less than the stress obtained by hexagonal rotor and occurs at the intersection of blade flange and hub (Singh and Ahmed, 2011).

In this research the blade is assumed to be a cantilever beam which is fixed at the hub and free at the tip and the load is considered to be applied flap wise uniformly distributed on the whole span (Pannase, Bhagat and Sakarkar, 2013). The uniformly distributed load is of the wind load which is acting on the blade due to wind pressure. The composite materials typically comprise fiberglass, carbon fibers, or wood together with a matrix of polyester resins or epoxy. The main advantages of composites includes ease of fabrication into the desired aerodynamic shape, high strength, and high stiffness to weight ratio. They are also corrosion resistant, are electrical insulators, are resistant to environmental degradation, and lend themselves to a variety of fabrication methods (Manwell, McGowan and Rogers, 2009). At later stage of this research, the natural frequencies of the blade when it is subjected to initial excitation of vibration is calculated analytically as well as on the FEA program. The material which was selected in this paper is glass fiber reinforced polymer and carbon fiber reinforced polymer.

## 2. STATIC ANALYSIS

The blade cross section was created in Catia from the imported coordinate's data of the selected airfoil and 3D model of the blade was prepared according to the dimensions given in the following table I.

TABLE 1: Wind turbine blade dimensions

No.	Particular of blade geometry	Value
1.	Root chord length	330mm
2.	Tip chord length	130mm

No.	Particular of blade geometry	Value
3.	Blade length	2500mm
4.	Hub diameter	67.5mm
5.	Hub blade to neck length	300mm
6.	Twist from root to tip	18°

The blade model was meshed with 2-D quadrilateral elements. A refinement mesh was generated around the curvature of the blade in order to get the accurate results. Model was composed of 4047 nodes and 4060 total number of elements in the mesh. Load applied on the wind turbine blade is the force which is exerted on the blade due to wind. The blade is considered to be a cantilever beam and the force acting upon it by the wind pressure is uniformly distributed over its length. Blade fixed at the section of hub near its neck while the tip is kept free, load applied on the face over the whole span of the blade.

The blade here was analysed for small scale horizontal axis wind turbine blade to be operated in the region of north Maharashtra considering the wind velocity 7.5m/s used for wind load calculation. Wind force was considered as uniformly distributed load (w) over the blade length, therefore can be calculated from the Eq. 1. (ASCE standard, 2006).

$$w = 0.613V^2 \times l \quad (1)$$

TABLE 2: GFRP and CFRP material properties

No.	Property of material	Unit	GFRP	CFRP
1.	Density	Kg/m ³	2200	1800
2.	Young's modulus	GPa	70	200
3.	Poisson's Ratio	--	0.22	0.22
4.	Bulk modulus	GPa	41.67	119
5.	Shear modulus	GPa	28.7	81.9
6.	Tensile strength	GPa	1.7	7.0

The deformation of the blade due to the uniformly distributed load of intensity 75.86 N/m over the whole length was calculated and maximum value was recorded as 6.03mm at the tip of the blade for GFRP material and that for CFRP as 2.72mm. The total deformation and deflection pattern of the blade using these materials can be observed in figs. 2(a) and 2(b) respectively.

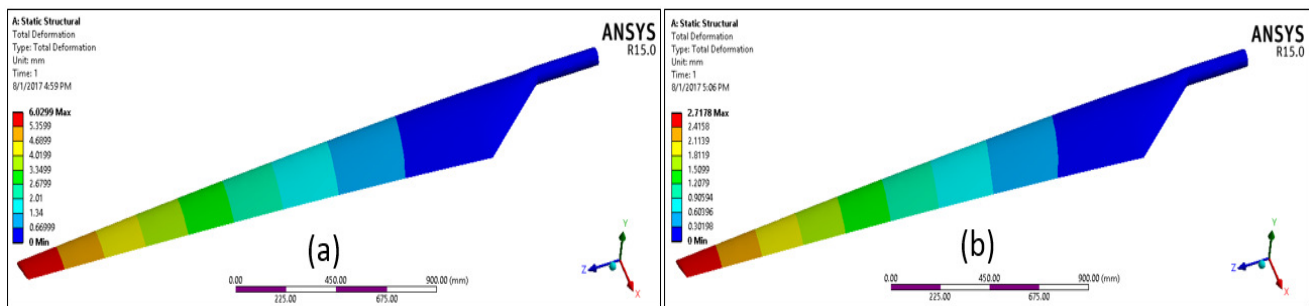


Fig. 2. Total deformation for GFRP and CFRP material blade

From Eq. 1 the load intensity calculated was 75.86 N/m which acts over the blade.

### 2.1 Equivalent stress:

The numerical FEA simulation shows maximum equivalent stress induced on wind turbine blade for both material was 13.25MPa occurring at the region near the hub as illustrated in fig. 1.

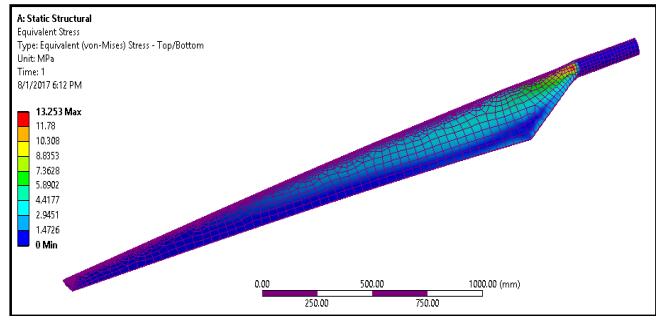


Fig. 1. Von-mises stress for both materials

### 2.2 Total deformation:

Materials used in the analysis of the blade was Glass Fiber Reinforced Polymer (GFRP) and Carbon Fiber Reinforced Polymer (CFRP). Properties of both the materials were given in table II.

### 3. DYNAMIC ANALYSIS

#### 3.1 Analytical calculations of natural frequency:

In this research, for dynamic modal analysis to find natural frequency of free vibration, the blade was modelled as Euler-Bernoulli beam and can be expressed mathematically as in Eq. 2;

$$EI \frac{\partial^4 y}{\partial x^4} + \rho A \frac{\partial^2 y}{\partial t^2} + C \frac{\partial y}{\partial t} = 0 \quad (2)$$

The relation between the eigenvalues and undamped

natural frequencies can be expressed as given by Eq. 3 and can be found at each mode of vibration,

$$\omega_n = \beta^2 \sqrt{\frac{EI}{\rho A}} \quad (3)$$

Where, the eigen function  $\beta = n\pi/L$ ; the corresponding natural frequencies can be obtained by Eq. (3), ( $n = 1$  to  $\infty$ ). (Muhammad, Kumar and Chaskar, 2014)

The natural frequencies for first five modes were calculated for both the materials from Eq. 3 and their result are shown in the bar chart below in Fig. 3.

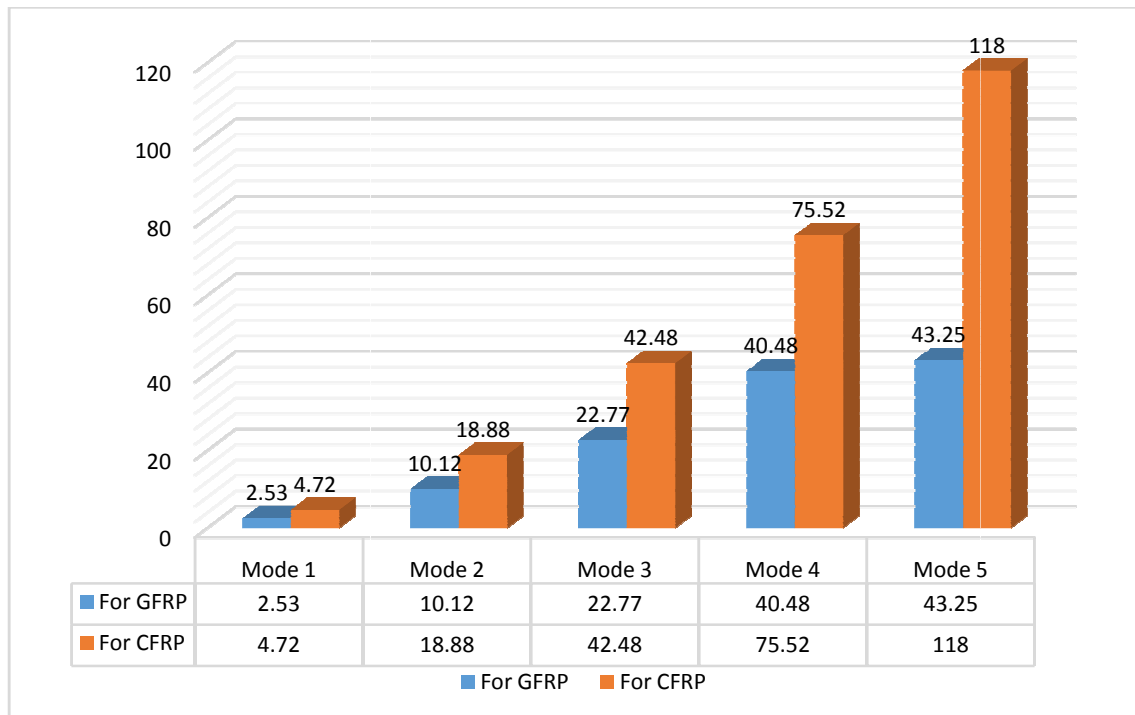
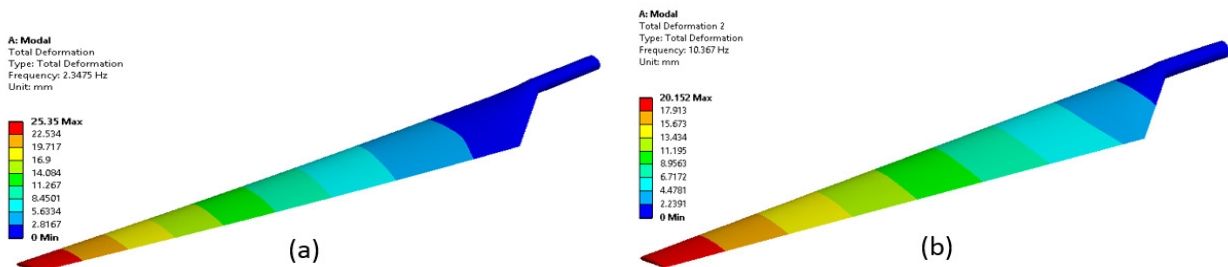
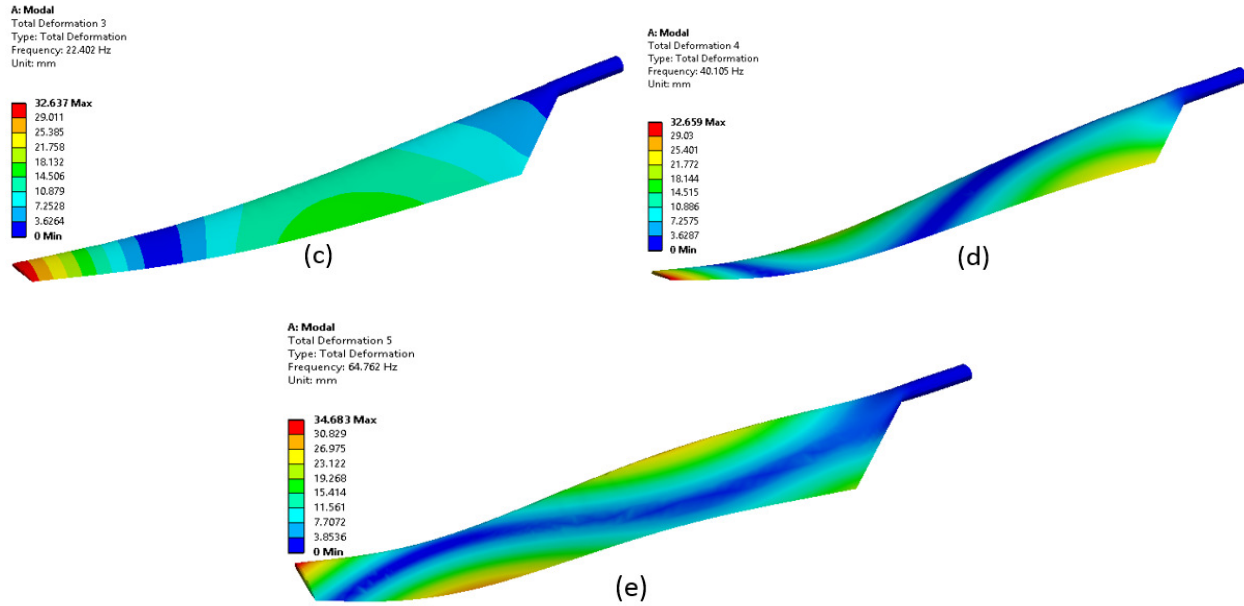


Fig. 3. Natural frequencies for GFRP and CFRP material by analytical method

#### 3.2 Modal analysis by ANSYS:

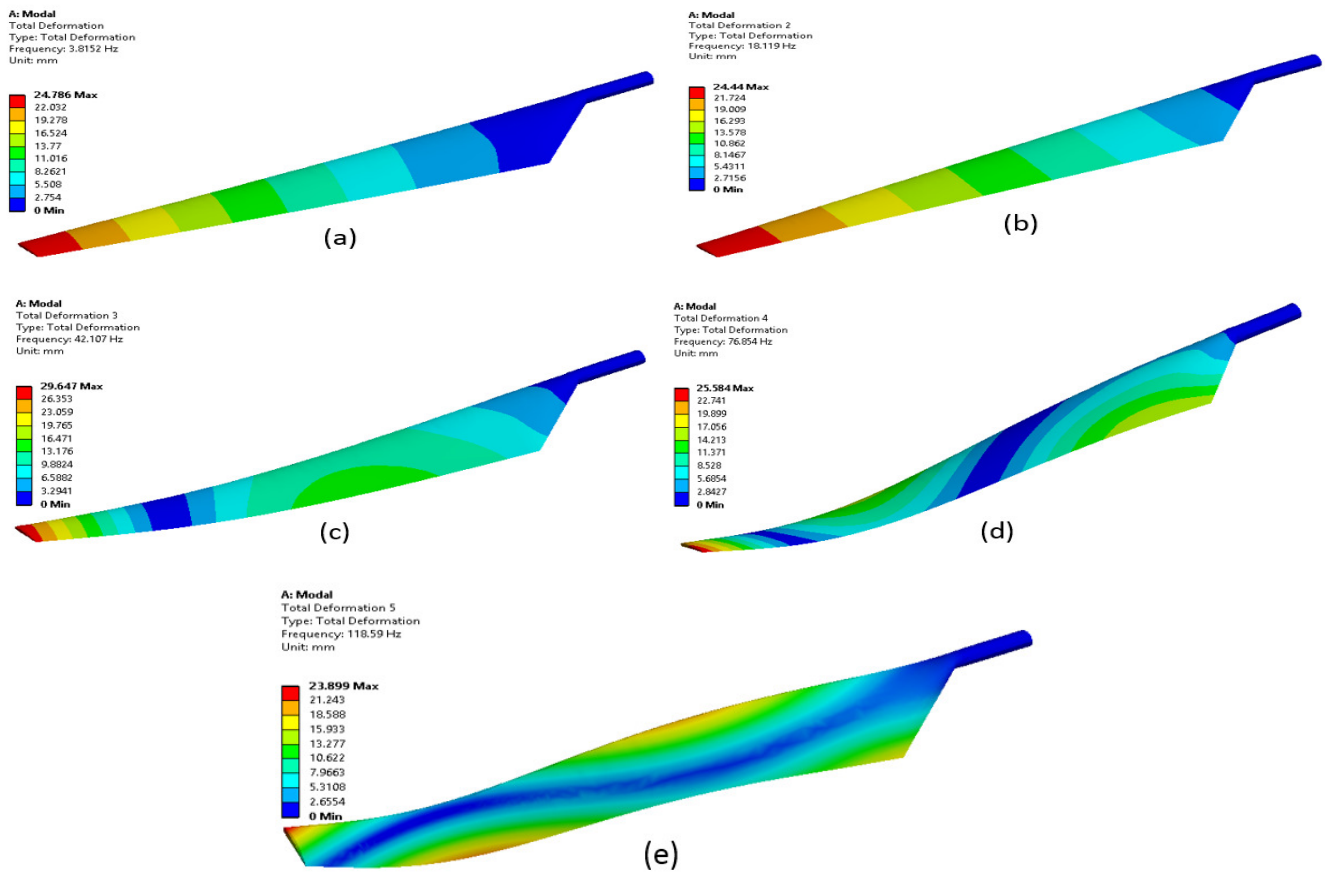
The first five mode shapes of the blade and their corresponding deflection patterns were illustrated in the figures below. Mode shapes of all the orders and their respective frequencies can be observed in the postprocessor results of analysis software.





**Fig. 4. Natural frequency of blade for five mode shapes fig. (a) to (e) with GFRP material.**

The natural frequencies of blade and their deflection contours at free vibration for first five mode shapes when the blade is modelled with GFRP and CFRP material can be observed in fig. 4 and fig. 5 respectively.

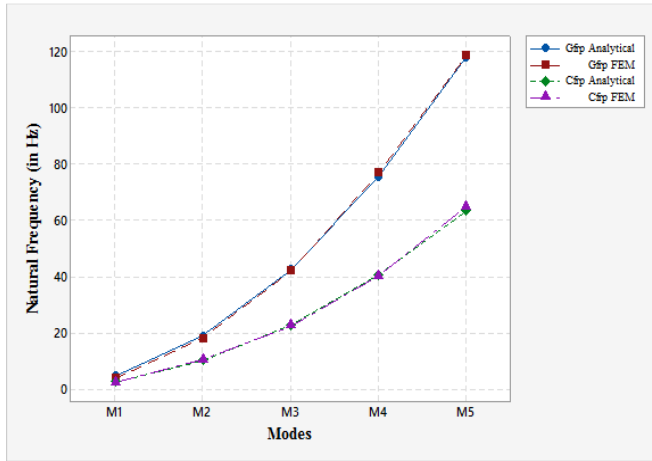


**Fig. 5. Natural frequency of blade for five mode shapes fig. (a) to (e) with CFRP**

The FEM model was simulated in ANSYS to extract the natural frequencies of the blade for each material at different modes and the results were tabulated and compared with their counterpart by analytical method in table III below.

**TABLE 3: Comparison of results for natural frequency by analytical and FEM method**

Sr. No.	Material	Method	Natural frequencies in (Hz)				
			Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
1	GFRP	Analytical	2.53	10.12	22.77	40.48	63.25
		FEM	2.35	10.37	22.40	40.11	64.77
2	CFRP	Analytical	4.72	18.88	42.48	75.52	118.00
		FEM	3.82	18.12	42.11	76.85	118.59



**Fig. 6. Comparison of natural frequency by analytical and FEM method**

#### 4. RESULTS AND DISCUSSION

There was 4047 nodes and 4060 total number of elements generated in meshing of 3D model in ANSYS. In FEA analysis it is observed that the results converge more to the accuracy when the size of the mesh used was fine rather than coarse. But the time required for the calculations of the results for fine mesh is increased than required for coarse mesh.

The numerical FEA simulation indicated equivalent stress on wind turbine blade for both material was same in the range of 0 to 13.25MPa, maximum occurring at the region near the hub. While the total deformation of the blade due to the uniformly distributed load was varied for both materials in consideration. Total deformation of 6.03mm at the tip of the blade was observed when analysed by using GFRP material for the blade. It can be seen that the result for maximum equivalent stress when the blade is analysed by using CFRP material was 13.25MPa same as obtained in GFRP, but in case of total deformation it was 2.71mm at the tip which is less than the previous material.

The comparison of given in table III shows that the blade with CFRP material gives better results and their

corresponding natural frequencies are more as compared to that of the other material.

#### 5. CONCLUSION

In order to explore the influence of different materials on the static and dynamic behavior of the wind turbine blade which is useful for designing the blades, the dependence of response on the initial excitation was studied. It is concluded that when the blade was modeled by using carbon fiber reinforced polymer (CFRP) gives always better results than the blade when modeled by glass fiber reinforced polymer (GFRP). The simulation result indicated that blade with CFRP material has higher tensile strength and Young's Modulus, thus it gives less total deformation in static structural analysis. FEA results of modal analysis are found to be agreed well with those of analytical results. In case of natural frequency of modal analysis also, the CFRP blade showing more stiffness having more natural frequency. From the comparison of static and dynamic modal analysis for both material blades of wind turbine, it was observed that CFRP material blade yielded good results.

#### ACKNOWLEDGEMENT

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# Accelerometer Operated Intelligent Wheelchair

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**Abstract:** Many paralyzed people face a variety of problems in their daily life. They require help from others to meet their daily requirements. The most important aim of this paper is to provide an automated system for physically disabled persons. The wheelchair works with respect to the movement of head of the user. The user gestures are used to produce motion control commands for the controller so that wheel chair is moved according to user's intention. Quadriplegic patients are those persons whose body parts below the neck does not work and the only way they can give commands is through head gestures. The accelerometer fitted on the wheelchair detects the head movements and the controller processes the signals which then will control the navigation as per the information given by the user. This autonomous navigation helps maintain an intelligent user interface and ensures safety, flexibility, mobility and obstacle avoidance as well. In addition to this, there is a real-time communication system in the wheelchair, which allows the interaction between the patient and the mentor.

**Keywords:** Automated system, Automated Wheel chair, Gestures, Quadriplegic Patients, Accelerometer Sensor, Autonomous navigation, Intelligent Interface.

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## 1. INTRODUCTION

A lot of people have lost their limbs in accidents, wars, and injuries of spinal cord. These people have to depend on the aid of wheel chair for their portability. There are many types of wheelchairs available in the market having automated power supply for their wheels and which use joystick (or touchpad) for navigation. Generally, these wheelchairs require self operation and a mentor to look after and safeguard the patient. According to a study conducted, the main causes of paralysis is spinal chord injury.

The proposed wheelchair helps such patients to move their head accordingly in order to give commands. The head movements control has proved very useful for those who have spinal cord injury (quadriplegia). This wheelchair will basically serve useful for the patients in order to fulfill their mobility needs. The key reason for developing this paper is to help such patients lead their life independently. Paralysis of nerve cells and muscle fibers can result in bringing in locomotive challenges. The objective of this paper is to use the concept of gesture recognition (GR) in order to control the mobility and a few other aspects of the wheelchair. The used GR technique avoids the ambiguity in recognizing the various commands given by the patient in terms of head movements in various directions.

## 2. LITERATURE REVIEW

Several wheel chair designs are discussed in the literature. The wheelchair is designed to bring in movements in both indoor environment [4] and outdoor environment. In case there are any changes observed in the surrounding environment of the wheelchair (such as rain or snow fall),

the smart device attached to the wheelchair senses this and an immediate SMS will be cast to the mentor regarding the same. GSM (Global System for Mobile Communication) and GPS (Global Positioning System) [1] systems present in the smart device is used for establishing a connection between the patient and the mentor and for tracking the patient's location. Controllers such as head tilt controllers and voice controllers are embedded in the wheelchair, so that, the quadriplegic patient's [2, 3] intentions can be read. In case the patient is blind, the voice controller will prove to be very helpful.

## 3. DESIGN AND DEVELOPMENT OF WHEELCHAIR

Fig 1 shows the block diagram or the overall structure of systems. It constitutes a sensor design, a mechanical module and an electronic module. The accelerometer is present in the sensor design. The electronic module has a microcontroller. Lastly the mechanical module consists of driver IC (integrated circuit) and motors respectively.

Basically the demo chair fitted with four wheels for movement is controlled by DC motor and the functional unit driver accelerometer sensor is fitted on the patient's forehead which comprises a microcontroller unit. The person simply needs to tilt his head for movement of the chair. The signal received from the sensor is in the analog form. And by using ADC (analog digital convertor), the signal will be converted into digital format and processed by the microcontroller unit.

The patient can move the chair in four different directions: front, rear, right, left and stop, by tilting the head in five different axes. The wheelchair is equipped with a display

system (smart device), which guides the mobility and displays the patient's health conditions. If any variation happens, the controller sends an SMS through GSM to the hospital and the mentorto indicate the patient's condition.

The mechanism of GR Technology is primarily achieved with the help of accelerometer and the proposed wheel chair. For gesture recognition, the accelerometer calibrates and filters the data. It is possible for the accelerometersto measure the magnitude and direction of gravity along with movement induced acceleration.

### 3.1 EEG (Electroencephalogram) System

In order to detect the head movements, the gyroscope Emotive EPOC headset is used. EEG activity can be measured with the help of 14 saline electrodes in the device Emotive EPOC headset.The saline electrodes are put in order according to the 10/20 system, O2, P8, T8, FC6, F4, F8, AF3, F7, F3, FC5, T7, P7, O1, and AF4 are the respective locations.The Nav Chair has an application for the development and testing of shared control systems, wherein a human and the machine can interact very conveniently and can control the working of the system. And the machine can very easily adapt to human behaviors. The Nav Chair is very easy to operate as a few commands such as obstacle avoidance, safe object approach, maintenance of straight path and many more can be easily accepted and processed. There is a smart device attached to the chair and Touch screen technology is present in it which is adapted by the wheelchair. This smart device is connected to the motors through the micro-controllers.It makes it possible for the patient to achieve locomotion independently with the help of a touch screen application

present in the smart device.In case the direction has to be altered, the touch screen sensor is framed to direct the user to the required destination with the use of direction keys on the screen. And finally those values are castinto micro-controller.The micro-controller controls the wheel chair directions with respect to the direction selected on the touch screen.By altering the average voltage sent to the motor, the speed controller is being worked. This is achieved by switching the motor supply on and off very rapidly using the pulse width modulationtechnique.Though all of the analyzed systems are very much advanced, they are neither too complex in operation andnor too complex in their circuitry and they are not financially economical as well.The developed wheel chair system is comparatively easy to operate, has a good response and isquite economical for most of the users.

### 3.2 MEMS

Micro-electromechanical system (MEMS) is system which enables technology for temperature sensors and acceleration. The sensor products which are MEMS based, provide an interface that can sense, control or process the surrounding environment.MEMS is the most general form of technology.And it can be defined as minimized mechanical and electro-mechanical elements (i.e., devices and structures) which are built using the techniques of micro fabrication.Very small electrical and mechanical components can be built on a single chip of a class of devices that are based on MEMS sensors.MEMS based sensor is an important part in automotive electronics, computer peripherals, hard disk drives, medical equipment, wireless devices and many more.

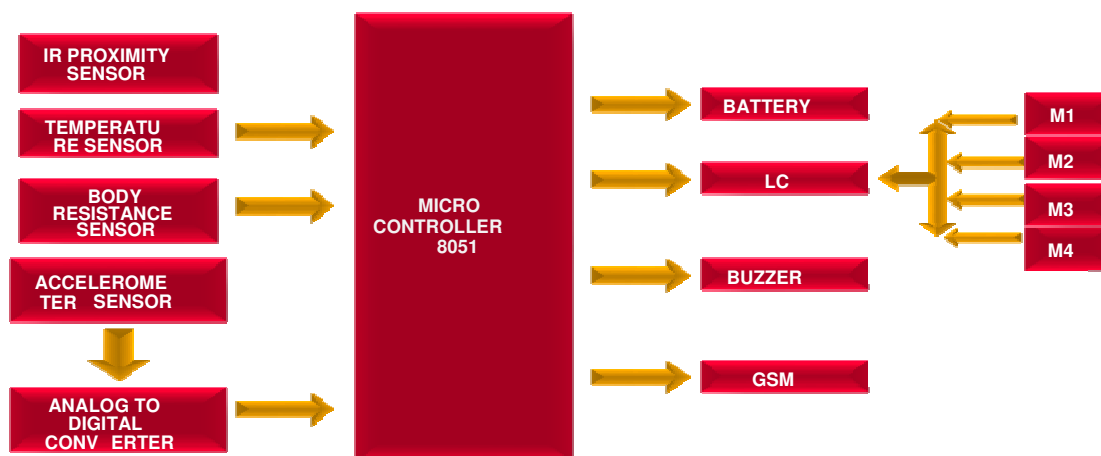


Fig. 1. Block Diagram of Functional Unit

The technical specifications are:

- Operating voltage of embedded circuitry is 5v DC.
- Current consumption of device in active mode is 200mA (mill ampere).
- Operating frequency of device is 11.0592MHz.

Some of the key elements of MEMS are compressed (small)microelectronics, structures, sensors and actuators. Micro sensors and the micro actuators are the most notable elements. These two are categorized as “transducers”.

The device basically converts the measured mechanical input into an electrical signal in case of micro sensors. MEMS technology puts forward a few benefits such as less power consumption, miniaturization, high output in terms of performance and cost-effectiveness. To deteriorate the component count, the functionality can be mounted on the same silicon package. In this way, the cost savings can be achieved.

#### 4. CONCLUSION

The wheelchair can very conveniently fit into both indoor and outdoor environments. The concept of IOT(Internet of things) is being used in this wheelchair which makes the patient more independent. It is not restricted only to quadriplegic patients, but for old and blind people as well. The wheelchair is not equipped with highly expensive sub-systems, which makes it very economical for a middle classed person. In future, with the cost flexibility and the advancement in technology, the wheelchair can be provided with a direct mind reader, which as the name itself indicates, can directly take commands from the patient's mind. It will be very helpful for the society if the government supports the needy with more such facilities with good quality.

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# Medical Product Development Process: An Exploration of Sources of Risks

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**Abstract:** Risks during Medical Product Development may have catastrophic effects and have origin in few sources.

*This paper explores 10 sources of risks in Medical Product Development process through exploratory approach and discusses those in detail. A literature survey and opinions of experts engaged in development of different medical products are used to explore the sources. The study will help manufacturers and developers to identify, analyse risks stemming out of these sources and develop mitigation measures, which will ultimately reduce failure rate of medical devices during different stages of MDD.*

**Keywords:** Medical product development process, sources of risks.

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## 1. INTRODUCTION

In spite of improvement in healthcare due to breakthrough research and innovations, medical devices always introduce a risk of harm or adverse event to users. Conducting an effective MDD process is essential from the business perspective as the device itself presents a risky investment opportunity with a high chance of failure due to stringent regulatory processes and potential litigations (Medina et al. 2012). MDD processes are less structured as compared to business or manufacturing processes; have number of interactions and are driven by potential risks stemming from different sources at each stage of development. The inherent complexity of the devices with increased regulatory, cost and time pressures forces device developers to expand their risk horizon beyond pure design risks (Pietzsch et al 2009) towards sources of risks which potentially jeopardize MDD processes.

Ten sources of risks in MDD process are explored by semi structured interviews of MDD experts and comprehensive literature survey.

## 2. LITERATURE REVIEW

This literature review is related to risk perspectives of MDD and applications of SEM to various fields.

### 2.1 MDD and risks

A comprehensive literature survey was conducted to identify risks in MDD process and their sources. While ISO 14971:2012 specifies risk management process for medical

devices, effective product development is a critical issue for medical device manufacturers (Ciurana 2014). Peer reviewed research articles from search engines like Emerald, Taylor & Francis, Elsevier, Springer Link, and Google Scholar were referred with keywords – medical device development, risk analysis, risk management, risk assessment, medical device design, and medical product development. According to the international testing body Intertek, out of every ten devices nine fail in their first prototype test, a 90% failure rate (Aguwa et al. 2012). Some researchers have analyzed risks in medical device design, few have reported on MDD process. Schmland et al (2005) provided practical ideas to allow medical device manufacturers to assess residual risk of their devices. Bracers et al (2008) presented risk analysis of dental implant using failure mode and effect analysis (FMEA). Lindholm and Host (2009) presented risk identification by: physicians, developers and software developers during procurement of a patient monitoring system. Cheng et al. (2011) used failure modes, mechanisms and effect analysis (FMMEA) to identify root causes and effect mechanisms in failure of infusion pump. Schraagen and Verhoeven (2013) reviewed user-interface issues with infusion pumps as a case because of its relevance to patient safety and found that although infusion pumps have contributed to improvements in patient care, they are not without risks.

Chan et al. (2012) integrated risk analysis (ISO 14971) and failure analysis (FMEA) to assure device quality in the design phase of MDD with case of ventilation breathing circuit. Lin et al. (2014) presented human reliability

assessment of medical device using Fuzzy FMEA. Kirkire et al (2015) used FMEA with fuzzy linguistic approach for risk management in medical product development process and proposed a comprehensive risk mitigation model.

After review of literature, it is observed that research related to risks in MDD is limited to specific cases restricting its applicability in wider context of MDD. It was found that risks stem out of few sources which have catastrophic effects. Hence, this research focuses on identification of sources of risks in MDD process.

### **3. SOURCES OF RISKS IN MDD PROCESS**

Though MDD teams know they must include risk management as part of their development strategy to help reduce risks; identification, assessment and tracking risks in MDD process is an incredibly time consuming task and rarely gets the attention it requires (Borcherding2013). Ten most significant sources of risks in MDD process as identified and discussed in this section.

#### ***3.1 Poor communication among device developers, end users and marketing people(R1)***

When a MDD process or device fails, it is failure of entire team - due to wrong assumptions about users while operating and developers while designing and developing; both can be equally harmful. Need for medical devices are often felt by clinicians and ideas are conveyed to scientists or engineers who develop devices but have little or no experience as device users, it sometimes leads to development of devices which do not meet user needs. Involvement of users in MDD is rewarding on the contrary non involvement will lead to development of devices with significant issues/problems (Shah and Robinson 2007). Marketing people convey voice of customers to developers and vice versa which ensures that user needs are met (Pietzsch et al 2009). Device developers make incorrect assumptions about user needs and marketing personnel make incorrect assumptions about needs of designers, which has serious consequences that may not be detected until late in the development process (FDA 1997). A strong communication among device developers, end users and marketing people leads to successful MDD; whereas poor communication may lead to commercial and technical failure of devices.

#### ***3.2 Ambiguity about end users and their requirements(R2)***

Medical device users vary greatly in their physical, sensory and mental abilities (Martin et al. 2012). The requirements of these users vary from each other. Users discard the devices which fail to meet their requirements though manufacturers, developers and healthcare professionals consider those requirements are met (Shah, Robinson and Alshawi2009).

In order to increase the likelihood of producing successful devices, developers must have a clear and thorough understanding of appropriate users who will use the device along with a range of physical and organisational environments within which the device will be used (Martin & Barnett 2012).

UK national health services (NHS) investigated that, during 2007 out of all the deaths and severe incidents included those where developers had not clearly understood the context of use of their devices. The devices had not been designed with user expectations in mind (Martin et al. 2012).

#### ***3.3 Poor translation of user requirements to device design parameters(R3)***

User requirements must be clearly translated to device design parameters during MDD. Design parameters include specifications of performance limits, operating tolerances, operating environment, physical dimensions and material specifications. A World Health Organization (WHO) study concluded that, devices are often not well designed for the environment in which they are used. User requirements should be clearly translated to design parameters.

For instance, it is would be insufficient to state that a catheter must be able to withstand repeated flexing. The better requirement should state that the catheter should be formed into a 50 mm diameter coil & straightened for a total of fifty times with no evidence of cracking or deformation (FDA 1997).

#### ***3.4 Poor planning for regulatory approvals, clinical approvals, testing and key decision points(R4)***

Regulatory requirements substantively impact the manner in which medical devices are developed and brought to market and by impacting time to FDA approval largely determine when the device can be brought to clinic (Pietzsch et al. 2009). Developers have to meet regulatory requirements before launching devices to market. Developers sometimes bypass the review process using loopholes in regulatory systems which may lead to future consequences and financial setbacks to developers. Regulatory approvals, clinical approvals, and testing activities must be properly planned to avoid future delays and consequences.

#### ***3.5 Improper or poor assessment of progress by reviewers (R5)***

Design review is a documented, comprehensive and systematic examination of a design to evaluate the adequacy of the design requirements to evaluate the capability of the design to meet these requirements and to identify problems (FDA820.3(h)). As the design progresses, design reviews at key points allow changes to be made without significantly affecting the schedule.

The review team consists of individuals with experience and expertise in specific discipline based on type of device along with persons involved in the device development. Apart from conflicts of interest of experts and clinical investigators, lack of impartial and effective knowledge of reviewers may cause underestimation of risks of device failure (Mol2014).

### ***3.6 Lack of or poor consequential risk assessment(R6)***

FDA expects the device manufacturers to have a complete risk analysis and management process in place. Risk modelling carried out for estimation of device failures during consequences are useful to reduce or estimate likelihood of failures. Analysis of devices failed on large scale (eg. Hip prosthesis) reveal that likelihood of technical failure was underestimated (Mol2014). Development teams ignore some risks to reach devices early to the market which results in further consequences and even an adverse event.

### ***3.7 Poor consideration to the effect of labelling and packaging(R7)***

Labels and packages form final link between medical device developers and end users. It must assure legible and long lasting print on device until used (FDA 2012).

Several deaths have been reported due to poor labelling. An example of it is death of patients reported due to unclear instructions on HeartMate II LVAD (Left Ventricular Assist Device) used to improve survival and quality of life for a broad range of heart failure patients (Newmarker2014).

In other instance 4,71,000 insulin syringes were recalled under class I in year 2008 by FDA. The packages were labeled for use with U-100 insulin but actually contained a syringe designed for use with U-40 insulin leading to risk of insulin overdose (FDA).

On the other hand, packaging can reduce likelihood of errors. For instance: syringes and needles are packed together which eliminate the possible error of mismatch due to size of the two.

Healthcare professionals or patients often have little time to read the multitude of device manuals or instructions carefully due to time and capacity constraints (Dankelman2010). Hence, proper labelling and packaging is most important.

### ***3.8 Lack of use of adequate standards to check/assess device performance or during validation(R8)***

Validation is mandatory requirement of medical devices and confirms to defined user needs and intended use of device. It includes testing of production units under actual and simulated use conditions (FDA 1997). Medical device

developers/ manufacturers launch the devices to market by ignoring standards which in turn lead to adverse events. The offset cup impactor is reusable instrument used during acetabular replacement surgery to implant an acetabular cup (FDA). Offset cup impactor developed by Greatbatch Medical was recalled under class I in 2014. Internal sterility assurance level validation identified that a specified assurance level was not achieved on standard offset cup impactor when subjected to steam sterilization cycles and associated dry times specified in current instructions for use provided with devices (FDA 2014). Class I recalls are situation in which there is a reasonable probability that the use of or exposure to a violative product will cause serious adverse health consequences or death (FDA). Standardization is a key issue in the field of medical devices and would reduce number of accidents (Dankelman2010). Use of appropriate standards is much essential for successful MDD.

### ***3.9 Lack of training to end users(R9)***

While developing a medical device, opinions of clinicians is taken. In practice the devices are operated by multiple end users like - nurses, patients and their relatives who have different physical, emotional and cognitive abilities. Lack of training results in poor usability of device and increases risk associated with the device (Martin et al. 2006) which in turn results in adverse event (Dankelman2010). Proper training reduces user related errors and risks.

### ***3.10 Unmet user needs/requirements (R10)***

Identifying unmet or poorly met clinical need is often a starting point for successful MDD (Martin et al. 2006). The clinical need is what clinicians want in order to overcome a particular issue under clinical/surgical settings. Medical devices have multiple end users like - physicians, patients and caregivers, etc. who have different functional and behavioral characteristics (FDA). Performance of devices gets affected by clinical environment such as - intensive care unit, casualty wards, emergency transport ambulance medical camps, etc. and non clinical environments such as high temperature, humidity, dust, poor illumination, etc. Proper analysis and validation testing of devices using appropriate analytical and simulation approaches must be done to meet all user needs. Devices unable to fulfill user requirements are quickly discarded by users even though manufacturers and healthcare professionals may consider those end users' requirements met (Shah et al. 2009). Clearly specified user needs, constraints and technicalities aids proper planning of MDD process leading to development of efficient devices (Pietzsch et al. 2009). The devices having usability problems might be rejected by their users since they fail to meet their needs and skills, which in worst case may even lead to a financial lack of viability of the device (Shah and Robinson 2007).

#### 4. DISCUSSION AND CONCLUSION

This research has explored 10 most significant sources of risks in medical product development process based on opinions of MDD experts and review of relevant literature.

The existing literature related to MDD has mainly focused on aspects such as: quality and user engagement. The aim of this study was to explore the sources of risks during medical product development. These sources have been explored with the opinions of different levels of experts engaged in medical product development such as: M.D, director, vice president, design engineers, manufacturing engineers and quality engineer. The use of open ended, semi structured interviews as mentioned by Martin, J. L, et. al. (2012), made participants feel free to share their views.

Following few measures are recommended which will help to reduce failure of medical product development process and devices-

- Strong marketing team should be developed to have continuous interaction with end users.
- All probable and potential users of device should be clearly defined
- Role of users during each stage of development should be specified to avoid adverse/undesirable events related to device users.
- Independent reviews should be conducted along with team reviews.
- It is always beneficial to involve clinicians during each stage of MDD which will certainly help to reduce failure events of MDD processes and devices.

The design and development activities are dominated by only few key personnel, people from different functional areas are less involved in activities such as risk analysis. Proper planning for it is extremely needed. This paper will act as a guide to understand the sources of risks in medical device development process. Also the risks stemming out of these sources can be identified and customized risk mitigation measures/strategies can be developed by the developers.

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# Automatic Color Sorting Machine

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**Abstract:** History of sorting or hand picking dates back to Stone age where prehistoric man made simple implements from hand sorted flints. The technological advances in all aspects of manufacturing but still sorting is a process which is done manually in almost every industry especially food processing in India. The manual color sorting is popular in industries as it requires less skill and ease of operation. It has few drawbacks such as less accuracy in manual inspection, slow processing etc. The manual color sorting process creates operator fatigue and frequent mistakes during operation this relates to boredom and employee attrition in the industry. To overcome these drawbacks the idea of automatic sorting came into being. The advantage of providing automation would relate to only initial investment and overhead due to electricity and maintenance.

The basic of color sorting involves image processor technique with the use of CCD or CMOS. Image processing technique is extensively used in colour sorting, in various industries. The major issue of color sorting involves image processor technique with the use of CCD or CMOS integrated cameras and expensive software which required for comparison of checked sample with a references.

The solution to all these problem is use of colour sensor for distinguishing the products of different colors. Such machines are widely used in packaging industries. The system is built by using microcontroller (ARDUINO UNO), color sensor, two servos, frame tube and a few customized 3D printed parts.

The different colored objects used in present case are such as fruity pebbles or gems are fed through feeding system comprising of hopper with a mechanism to pass only one object at a time. The object falls onto a wedge of the ring. This ring is made to move on a disc provided with slots which extend towards an opening into different containers. The colour sensor is placed just in front of the wedge such that the colour of the object gets detected and then signal is send to the servos through ARDUINO. The upper ring rotates and places the object in the required slot and while retracting it pushes the object into the cavity. The aim is develop a sorting machine for sorting components of different colors and counting the total number of objects sorted.

**Keywords:** Arduino microcontroller, TCS color sensor, servo motor, etc.

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## 1. INTRODUCTION

Machines can do the repetitive tasks better than human beings. When the operations are done manually, will result in Worker fatigue on assembly lines. And eventually this can lead in reduced performance, and cause challenges in maintaining product quality. A worker performing an inspection task manually may eventually fail to distinguish the color of product. Automating many of the tasks in the industries may help to improve the efficiency of manufacturing system.

Color detection is an important task in a wide range of industrial areas. For instance, medicines, agricultural products, chocolates, and all kinds of textile products are according to significant color features. The purpose of this model is to design and fabricate a system which will segregate products based on their color.

A typical colour sensor is based on a photodiode which measure the intensity reflected by the object for a red, green and blue light source. More advanced systems may use more colours or more specifics colors, such as orange

light sources of different wavelength in order to detect the hue of an orange. Some sensors, like the one used in this project, used the same principle but with three or more photodiodes with green, red and blue filters in front of them. In this case the light source may be white.

Systems with color sorting are used in many automated applications to detect automation errors and maintain consistent quality at high speed of production. They are used in automated assembly lines to identify and classify products by colour.

## 2. LITERATURE REVIEW

The design of Automatic Colour Sorter includes certain critical components and the following research papers will help in evaluating and finalizing the components to be used and various parameters that influence the design and fabrication of the proposed prototype.

Mohammed Saifudeen et al., 2015 prepared a working model of automatic colour sorting machine with the use of TCS colour sensor and PIC controller. The frequency

output of TCS 230 is analyzed and accordingly output is sent to the DC motor which control the rate that which the object under the sensor is dropped in the container. The colour sensor used i.e. TCS colour sensor is programmable sensing module with build in light to frequency converter. An 8 x 8 array of photodiodes will be read by a light-to-frequency converter. Sixteen photodiodes have blue filters, 16 photodiodes have green filters, 16 photodiodes have red filters, and 16 photodiodes are clear with no filters. Basically human vision identifies together termed as colour coordinate system. The microcontroller is programmed in such a manner that once the object is under the photodiode array it select the particular colored filter with the help of select pin configuration so that the net output produced is highly accurate with no disturbances.

Tom Pearson et al., (2008) developed image sensing system for segregating components with red and white wheat kernel. Images of the single kernel was taken from three direction using mirror. The output of CMOS based colour sensor was send to the PC for real time signal processing. It consists of following components: Camera lens, direct X application interface, photoelectric switch, reflector lamps. Using Microsoft Windows operating systems, image manipulation in real time can be enabled by an application programming interface called DirectX. Direct X is a software used in gaming. For color sorting based on image processing, the PC operating system should have the capacity to operate in real time, with critical timings as short as two milliseconds. This rapidity in operations can be achieved by use of IEEE 1394 data transfer module which enables, real time direct memory transfer. This module does not require the computer processors or operating system to manage the data transfer. In other words, the camera is able to load the images into PC memory on its own, without additional processing by the PC.

Nathan Peterson (2015) developed a very compact model for sorting skittles of different colors by means of rotating discs. The components used in this type of sorting machine are 4 Arduino Uno, TCS3200 Color sensor, DC motors with gearboxes and LED. The machine uses an Arduino Uno, combined with a Zitrades color sensor module in order to determine the color of each individual candy. To ensure it is operating in an environment with sufficient light to make the color determination, it includes an illuminating LED, thereby limiting the chance that the all commonly tragic red/orange confusion leaves you with an unsorted pile. After the color reading of each Skittle is complete, they are sorted with a series of gears, each into a tray with only it's like-colored mates.

Mark Randell (2005) studied and analyzed the method for sorting different colored translucent marbles. This research paper illustrates how the color of an object can be effectively sensed by scattering the reflected spectrum of

light by diffraction grating. This spectrum is made incident on photodiode array which produces signal proportional to the light striking it. The translucent characteristic of the marbles enable the light pass through the marbles. The marble will only allow the wave lengths of light to pass that correspond to the color makeup of the filter (marble). The filtered light is focused onto a diffraction grating, the spectra of this light will be spread out into it composite wavelengths allowing the color makeup of the light to be visible.

M.OMID (2009) et.al. developed an image processing technique for estimating citrus fruits physical attributes including diameters, volume, mass and surface area using image processing technique .The system consists of two CCD cameras, two capture cards, an appropriate lighting system, a personal computer and other mechanical parts. The calibration of system is done by samples of different grades of fruit. The volume and color of fruit determined and saved in database during calibration stage. During sorting stage, the calculated color and volume compared with saved information in database. The final grade of fruit was determined and its center of gravity calculated to be later used for automatic sorting through pneumatic mechanism. The two CCD cameras with 510 x 492 pixels were mounted about 25 cm above the belt and powered by a 24 V power supply. To provide uniform lighting, four fluorescent tubes, placed above the conveyor, were used. The position of the lighting tubes was adjusted to provide uniform, well illuminated and free from shadows images of fruit. The light source and cameras were mounted on a frame and were attached to the measurement table. A white cardboard is used as background surface to facilitate and simplify the segmentation task. Signals from lemon samples are captured by the camera, transferred to the PC through the video capture card, digitized, and stored on the PC in RGB (red, green, blue) color space. A program is developed to capture and record the surface images of the lemon.

Developed a machine which sort an object based on color. In this project hopper system, chain mechanism, Colour sensor, 4 servo motors with arm attachment and 2 servo motors for object movement and containers are used. It consisted of a feeding mechanism, colour detection, conveyer and push pull system. For feeding mechanism a hopper mechanism is used which is fitted with a reciprocating mechanism at the end of the hopper which moved a slot to and fro so that only one skittle is passed at a time. The color of skittle is sensed by colour sensor placed just below the hopper system. The skittle falls one by one on the conveyer system which leads it front of a push pull system. The push pull system consists of ejectors which are operated by servomotors.

### 3. DESIGN AND INTERFACING

After deciding the purpose of the system which is to sort different colored skittles or gems chocolate a 3D in Solidworks is developed with all the components customarily designed to suit a particular function.

#### A. CAD MODEL OF THE SYSTEM

A cad model is developed for the automatic sorting machine and is shown in the fig.3.1. The gems are fed through a feeder tube. The rotor will move one candy under the color sensor board. The colour sensor will sense the colour of the candy, and then the rotor rotates the candy into the respective channel corresponding to the colour. By reversing the rotor's direction, the candy is pushed down the channel and into the container below.

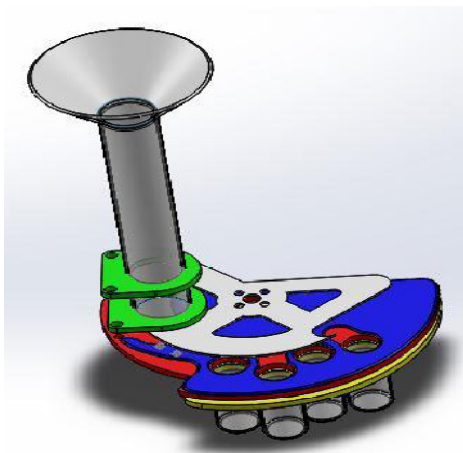


Fig. 3.1 Assembly Model

#### B. VIAL HOLDER

This structure is used for supporting the tubes or vials going to different containers. The part will be made of acrylic. It is provided with Ø25 mm holes for the gems to easily pass through it. Its function is to guide the gems into different containers. A clearance is maintained between the vial holder and the base with the help of spacers. Vial holder is shown in the fig. 3.2

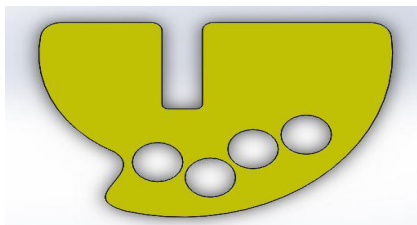


Fig. 3.2. Vial Holder

#### C. BASE

This part of the sorter is fastened to the separator with the help of machine screws and contains openings for the gems

to pass through the vial holders into the vials, and is shown in the fig. 3.3

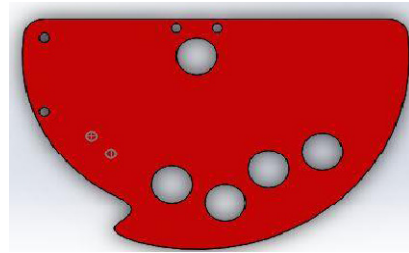


Fig. 3.3 Base

#### D. SEPARATOR

The separator has various slotted grooves which are covered on one side because of the base plate thus creating a hollow cavity in the region. The slotted grooves open up at the end to lead to the vial holders. The cad model of the separator is shown in the fig. 3.4.

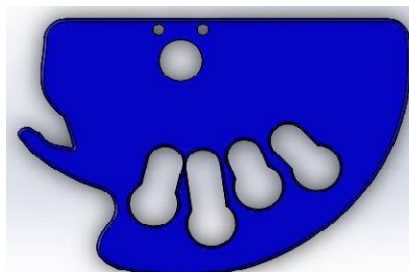


Fig. 3.4 Separator

#### E. ROTOR

A rotor is pivoted to move above the separator so that while rotating anticlockwise it will place the gems in the desired slot and while returning it will push the gems into the open cavity. The cad model of the rotor is shown in the fig.3.5.

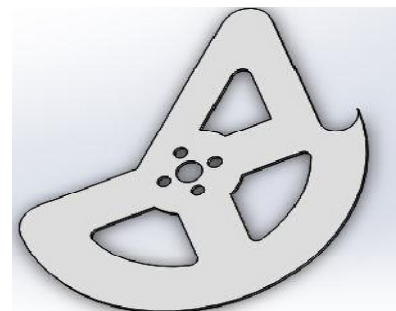
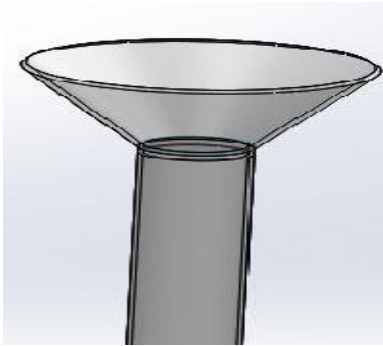


Fig. 3.5. Rotor

#### F. TUBE HOLDER

Use for placing the feeding tube in the required position above the separator and base assembly. The tube holder is positioned in such a way that the gems chocolate from the

tube will fall in the notched portion of the rotor. The cad model of the tube holder is shown in the fig. 3.6.



**Fig. 2.6 Tube Holder**

#### 4. ELECTRONIC COMPONENTS AND THEIR SPECIFICATION

##### A. TCS230 COLOR SENSOR

The TCS230 color sensor is a programmable light-to-frequency converter, which combines configurable silicon photodiodes and a current-to-frequency converter on single monolithic CMOS integrated circuit. The output of the sensor is a square, where the frequency will be directly proportional to light intensity (irradiance). The full-scale output frequency can be scaled by one of three pre-set values via two control input pins.

Using Microcontroller digital inputs and digital output pins direct interfacing of the sensor and actuator can be done.. Output enable (OE) places the output in the high-impedance state for multiple-unit sharing of a microcontroller input line.



**Fig. 3.1 TCS230 Colour Sensors**

##### B. SERVO MOTOR

A Servo system will have a controlled device, an output sensor and a feedback system. . Here, the device can be controlled by a feedback signal generated by comparing output signal and reference input signal. A comparator will compare the reference input signal with actual output and error signal generated and this signal is applied to the system,

##### Specifications:-

Torque - 4.8v: 3.2 kg-cm, 6v: 4.1 kg cm

Speed - 4.8v: 0.23 sec/ 60 deg, 6.0v: 0.19 sec/ 60deg

Weight: 37 g.

C. The Aurdino Uno microcontroller board with ATmega328 is used for this system. This controller has 14 digital input/output pins (of which 6 can be used as PWM outputs) and 6 analog inputs. It contains everything needed to support the microcontroller. The controller can be simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.



**Fig. 3.2 Microcontroller (Arduino)**

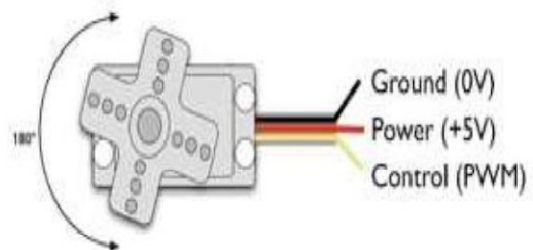
##### D. INTERFACING OF COMPONENTS

A servo has 3 wires:

Black wire: GND (ground)

RED wire: +5v

Colored wire: control signal



**Fig. 3.3 Pin Out of Servo Motor**

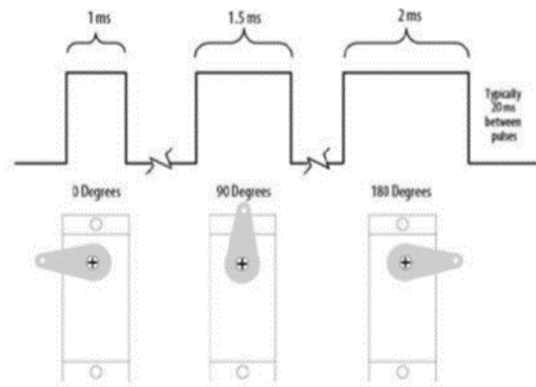
The servo has three pins. The third pin accepts the control signal which is a pulse-width modulation (PWM) signal. It can be easily produced by all micro- controllers and Arduino board. This accepts the signal from your controller that tells it what angle to turn to. The control signal is just a

pulse of varying lengths. The length of the pulse will decide what angle the motor turns to.

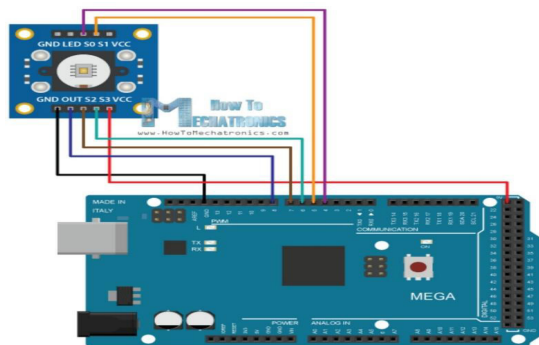
The pulse width sent to servo ranges as follows:

- 1 millisecond Corresponds to 0 rotation angle.
- 2 millisecond Corresponds to 180 rotation angle. Any length of pulse in between 0 and 180 will rotate the servo shaft to its corresponding angle. For example, 1.2 milliseconds pulse corresponds to rotation angle of 126 degree.

This is well explained in figure below.



**Fig. 3.4 Position of Servo Horn**



**Fig. 3.5 Connection Diagrams of TCS230 and Microcontroller**

## 5. RESULTS AND DISCUSSION

All the mechanical components are fabricated as per the dimensions of the cad model. The required sensors and

actuators are interfaced with microcontroller. The mechanical components are assembled with the sensors, actuators and microcontroller. Coding is written for the required color sorting of the components and down load in to the controller. The system is tested for color sorting of the gem chocolates and it is found the system is able to sort different colors with good accuracy. The fabricated model is shown in figure 4.1.



**Fig.4.1 Fabricated model**

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# Design and Development of Electric Scooter with Regenerative Braking

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**Abstract:** Electric scooter are plug in electric vehicles with 2 or 3 wheels powered by electricity. The electricity is stored on board in a rechargeable battery, which drives 1 or more electric motors. It is desired to develop and fabricate an electric scooter with regenerative braking so as to improve the performance and mileage of the existing electric scooters. A regenerative brake is an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. Regenerative braking is very common on electric cars, and rare on electric bikes. Regenerative means that the electric motor is used to slow down and generate electricity which is fed back into the battery which increases efficiency and range. It has mild stopping power and is used in addition to manual breaks. It is desired to develop and fabricate an electric scooter with regenerative braking so as to improve the performance and mileage of the existing electric scooters

**Keywords:** Electric scooter. Regenerative braking, etc

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## 1. INTRODUCTION

Electric scooter are plug in electric vehicles with 2 or 3 wheels powered by electricity. The electricity is stored on board in a rechargeable battery, which drives 1 or more electric motors. Most electric scooters today are powered by rechargeable lithium ion batteries, though some early models used nickel-metal hydride batteries. Electric vehicles has pioneered use of a lead silicate battery which is prevalent in automobiles. It is desired to develop and fabricate an electric scooter with regenerative braking so as to improve the performance and mileage of the existing electric scooters. In this study, we will be using ac DC motor. The electricity is stored on board in a rechargeable battery, which drives one or more electric motors.

A regenerative brake is an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. This contrasts with conventional braking systems, where the kinetic energy is converted to unwanted and wasted heat by friction in the brakes. In dynamic brakes, energy is recovered by using electric motors as generators. The most common form of regenerative brake involves an electric motor as an electric generator. In electric railways the electricity generated is fed back into the supply system. In battery electric and hybrid electric vehicles, the energy is stored chemically in a battery.

## 2. LITERATURE REVIEW

Jaya Aniruddha Mane and Prof. A.M Jain explains modelling design and control of a bidirectional dc-dc converter for EV applications. The provision for energy regeneration is achieved by using half bridge non isolated dc-dc converter. Small signal modelling of the system is done by the state space averaging technique. A PI controller has been implemented for speed control. The soft switching technique has also been incorporated to minimize the switching losses. The system model has been simulated in the MATLAB/SIMULINK.

Saurabh Chauhan done Motor Torque Calculations for Electric Vehicles An important component that is an integral part of all electric vehicles is the motor. The amount of torque that the driving motor delivers is what plays a decisive role in determining the speed, acceleration and performance of an electric vehicle. Mr. Saurabh Chauhan, in this paper, aims at simplifying the calculations required to decide the capacity of the motor that should be used to drive a vehicle of particular specifications. All electric vehicles have one thing in common and that is that all of them use Direct current electric motors to drive the wheels. However, these motors are available with a number of variations in speed, size and method of operation. It is the torque that forms the part of the force to drive the wheels and set the vehicle in motion. In simple terms, the torque may be defines the turning power of the motor. Hence, this paper presents one such method of calculating the torque. Finally, the paper concludes that if the required torque calculated is not produced by the available motor



specifications then modifications can be made in vehicle parameters like Gross Vehicle Weight, Wheels size, Material of the wheels and transmission system.

Prof. S.S. Vanamane and Yakub Anwar Makandar describes bidirectional DC-DC converter fed separately excited dc motor for EV application. It states that Battery Fed Electric Vehicles (BFEVs) are required to function in three different modes namely: normal (steady-state) mode, acceleration mode and braking (regenerative) mode. During acceleration and normal modes the power flow is from battery to motor whereas during braking or regenerative mode the kinetic energy of the motor is converted into electrical energy and fed back to battery. The paper also displays a circuit diagram of Bidirectional DC-DC Converter with battery and DC motor explaining the buck/boost converter topologies along with their respective circuit diagrams showing current flow directions. Also, the control circuit of the bidirectional converter is shown to control the speed of the dc drive. Prof. S.S. Vanamane and Yakub Anwar Makandar suggest that one possible control strategy is to control the output voltage of the bidirectional converter using a PI Controller. The system model has been simulated in the MATLAB/SIMULINK. Finally, the paper concludes that the overall cost and volume of the battery operated electric vehicle is less with the least number of components used in the system.

Greeshma M S, Nayana J presents an isolated bidirectional DC-DC converter with high conversion ratio which can be used in Fuel cell electric vehicles. The simulation of converter with low voltage of 24 V and high voltage of 200V is done using MATLAB/SIMULINK with fuel cell as the input and BLDC motor as the load.

B Rajesh, M Sandeep discusses the switching losses in Bi-directional dc-dc converter and suggests the technique of soft switching to reduce them. It deals with the use of Bi-directional dc-dc converter for a battery fed electric vehicle drive system along with a closed loop speed control technique which is implemented using PI controller.

Sirs B Rajesh and M Sandeep have introduced the basic concept of isolated bi-directional DC-DC converter along with circuit diagram, circuit description, circuit principle and current flow pathway for various different modes of operation. For more clarity, a 10Kw prototype of the isolated bidirectional dc-dc converter is built and tested via simulation in MATLAB/SIMULINK for buck/boost topologies. Finally, the paper concludes that the performance of a battery operated electric vehicle system is satisfactory at different driving conditions and the proposed control technique with PI controller is suitable for electric drives.

### 3. DESIGN AND DEVELOPMENT

It deals with development and fabrication of electric scooter which uses an electric dc motor. The previous chapter gave an introduction to the concept of the project and literature review assistance in deciding the components to be used and the parameters that can affect the result

MOTOR HORSEPOWER(HP) CALCULATIONS^{[3][4]} :

FORCES ACTING ON SCOOTER ARE : -

1)WEIGHT AND ACCELERATION:

$$F_a = C_i \times M \times a$$

$C_i$  - mass factor=1.06

$M$  - mass of vehicle in pounds

$F_a$  - acceleration force in pounds

$a$  - acceleration of vehicle in mph/s=3 mph/s

$$F_a = (1.06 \times (300 \times 2.204622) \times 3) / 21.94$$

$$F_a = 95.8618 \text{ lbs}$$

2)WEIGHT AND CLIMBING:

$$F_h = M \times \sin \alpha,$$

$M$  - mass of vehicle in pounds

$\alpha$  - angle of incline=8.534°

$F_h$  - hill climbing force in pounds

$$F_h = (300 \times 2.204622) \times \sin(8.534)$$

$$F_h = 98.14731 \text{ lbs}$$

3)AERODYNAMIC DRAG FORCE:

$$F_d = (C_d \times A \times V^2) / 391,$$

$F_d$  - aerodynamic drag force in pounds

$C_d$  - coefficient of drag=0.9

$V$  - vehicle speed in mph=30mph

$A$  - frontal area of vehicle in sq.ft

$$F_d = (0.9 \times 0.192 \times 10.7639 \times 30^2) / 391$$

$$F_d = 0.80498 \text{ lbs}$$

4)AERODYNAMIC DRAG FORCE DUE TO RELATIVE WIND SPEED:

$$F_w = C_w \times F_d,$$

$C_w$  - coefficient of drag force accounting for relative wind speed=0.25

$F_d$  - aerodynamic drag force in pounds

$$F_w = 0.25 \times 0.80498$$

$$F_w = 0.20124 \text{ lbs}$$

5)ROLLING RESISTANCE:

$$F_r = C_r \times M \times \cos \alpha,$$

$C_r$  - rolling resistance factor=0.02 for medium-soft surface

$\alpha$  - angle of incline=8.534°

$M$  - mass of vehicle in pounds

$$F_r = 0.02 \times 300 \times 2.204622 \times \cos(8.534)$$

$$F_r = 13.08127 \text{ lbs}$$

6)TOTAL TRACTIVE FORCE:

$$\text{FORCE} = F_a + F_h + F_r + F_d + F_w$$

$$\text{FORCE} = 95.8618 + 98.14731 + 13.08127 + 0.80498 + 0.20124$$

$$\text{FORCE} = 208.0966 \text{ lbs}$$

7)HORSEPOWER(HP) CALCULATION OF MOTOR:

$$\text{HPWHEEL} = (2\pi/60) * (\text{FORCE} * V/550),$$

$V$  - vehicle speed in mph=30 mph

$$\text{HPWHEEL} = (2\pi/60) \times (208.0966 \times 30/550)$$



HPWHEEL = 1.188645 HP

HPMOTOR = HPWHEEL/ $\eta_o$ ,

$\eta_o$  – CVT efficiency

Assuming  $\eta_o = 80\% = 0.8$

HPMOTOR = 1.188645/0.8

HPMOTOR = 1.4858  $\approx$  1.5 HP.

Thus as per the calculations, we select 1.5 HP dc motor.

### 3.1 Simulation Model on Matlab Simulink

The system consists of a battery, a dc-dc bidirectional converter and an externally excited dc motor. The battery supplies the potential that the motor requires through the bidirectional converter. The bidirectional converter has two things to do, boost the input that it gets from the battery in

running stage when the throttle is given to the motor and, buck the same input when the throttle is released. This is brought by changing the load cycle of the bidirectional converter. The throttle input is connected to the bidirectional converter with a help of a potentiometer.

This potentiometer is connected in such a way that it controls the load cycle of the bidirectional converter. This changes the voltage that gets into the system. This change in the voltage that is applied to the motor, is less than that which the motor is generating in the braking zone through regenerative braking. Thus the voltage is fed back to the system and stored in the battery. This is the regenerative braking.

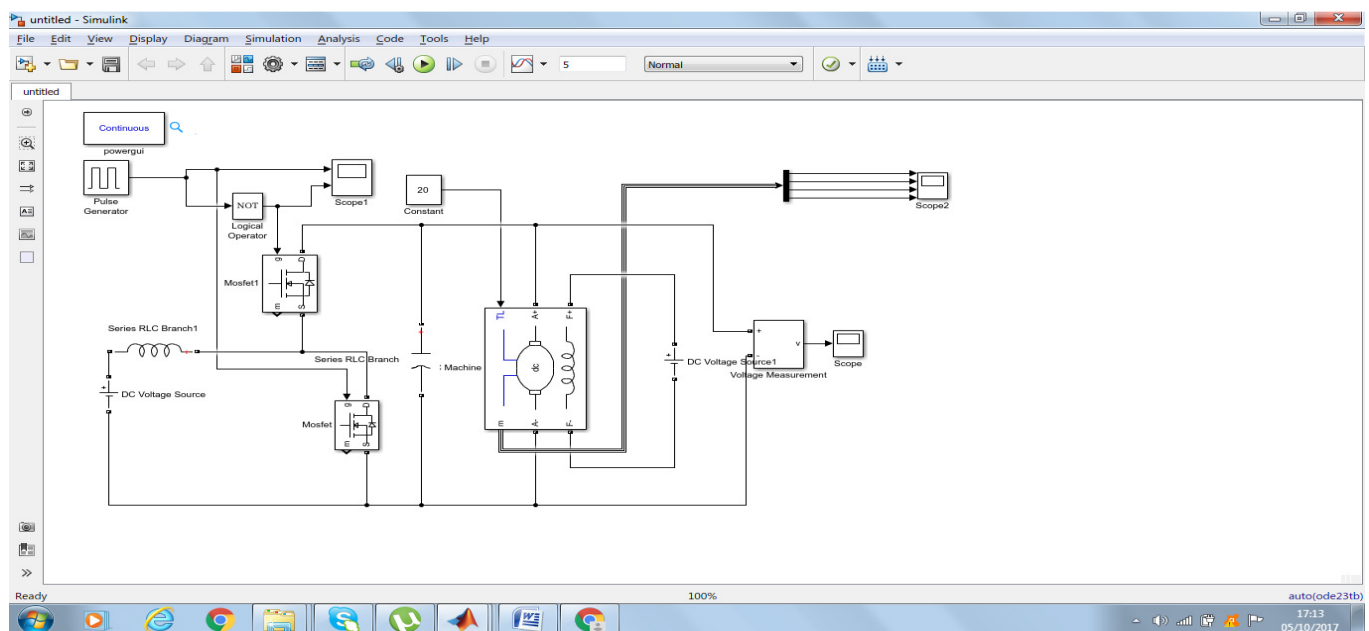


Fig. 1. Simulation model.

## 4. CONCLUSION

A simulation is been carried in MATLAB successfully, procurement of various components and its assembly is to be carried out.

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# Optimization and Design of Differential Gear Box Housing

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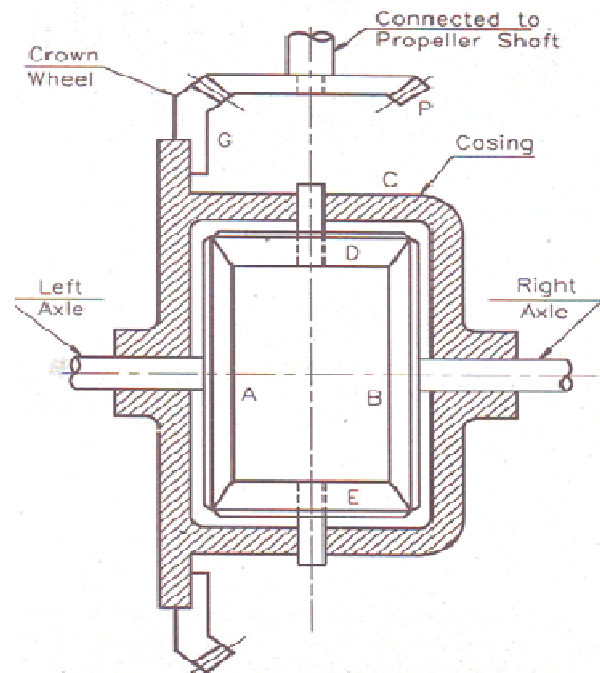
**Abstract:** Mass is one of the significant parameter while designing any automobile component due to its direct bearing on fuel economy & cost. With these objectives in mind optimization of components is carried out regularly. A case study of an optimization of differential gear box housing is described. The differential is an important subsystem in driveline of all modern cars and trucks. The differential gear box housing houses important components like axle, pinion, crown wheel, cage etc. The strength & rigidity of housing are important parameter while designing it. Finite element analysis of housing was done in ANSYS 10. Then topological optimization was carried out in ANSYS10. The objective was to minimize the volume keeping compliance & stresses nearly equal to or less than that of original model. Optimization was successfully completed & all desired objectives were met. The optimized geometry resulted in reduction of component mass by 22%. This resulted into more strength to weight ratio.

## 1. INTRODUCTION

Differential is a device that splits engine torque two ways allowing each output to spin at different speeds while taking a turn. It has been noted by designers that the design of the differential housing is done mostly on thumb rules and very less effort has been made to optimize the design through simulations. Therefore Differential gear box housing needs to be optimized to meet market demand of reduced cost of ownership. They are quite trouble-free, but do have one disadvantage. On a dry road with good traction, the power is evenly applied to both wheels. When one of the tires hits ice or a slippery surface, it begins to spin and the majority of torque is directed to the spinning wheel, leaving very little for the wheel with the good traction. This is how vehicles can get stuck in snow or mud.

Another type of differential is the limited slip differential, which is an option on most new cars. It has a distinct advantage by having a set of clutches and springs within the differential. Their function is to apply pressure to the side gears should one of the tires begin to slip. By applying pressure to the opposite wheel from the one spinning, it allows for more torque to be applied to the wheel with traction. It is far superior to the open differential when it comes to traction in bad weather.

CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components.



**Fig. 1a. Arrangement of gears in automobile differential**

Topological optimization capability of ANSYS has been successfully used to obtain concept design of differential gear box housing. Topological optimization in ANSYS uses density approach. In this the stiffness is assumed to be linearly dependent on the density. The material density of each element is directly used as a design variable, and is normalized to have a value between 0 & 1 representing state of void & solid respectively. The required specification of vehicle is given in Table 1

**TABLE 1: Specification of vehicle**

Sr.No.	Parameter	
1	Power	72HP@4000 r.p.m
2	Axle load carrying capacity	1134 Kg
3	Final drive ratio	4.27
4	First gear ratio	4.032
5	Maximum turning radius	6.08m
6	Material of housing	FG 400

## 2. PROCESS METHODOLOGY

Following step by step approach is followed to get an optimized shape.

### 2.1 Load Determination

**TABLE 2: Revolution parameters**

Step	Conditions of Motion	Revolutions of Elements			
		Crown Wheel G	Gear A(left Axle)	Gear D r Gear E	Gear B (Right Axle)
1	Crown Wheel G is fixed & A rotates through 1 rev.	0	1	$\frac{T_a}{T_d} = \frac{16}{10} = 1.6$	$\frac{T_d x T_a}{T_b x T_d} = -1$
2	Crown Wheel G is fixed & A rotates through x rev.	0	X = 25	1.6 x X = 1.6 x 25 = 40	- X = - 25
3	Add Y rev to all elements	Y = 232.2 r.p.m	X + Y = = 232.2 + 25 257.2 r.p.m	232.2 + 40 = 272.2 r.p.m	232.2 - 25 = 207.2 r.p.m

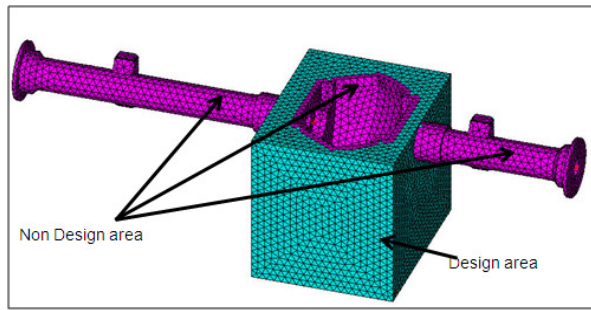
The major load coming on differential is due to driving torque, vertical reaction, tractive forces, braking forces & cornering forces. Following load cases were considered

**TABLE 3: Load cases**

Case 1	Torque load + Vertical reaction + Traction
Case 2	Torque load + Vertical reaction + Braking
Case 3	Torque load + Vertical reaction + Cornering (Left)
Case 4	Torque load + Vertical reaction + Cornering (Right)

### 2.2 3D CAD Modeling

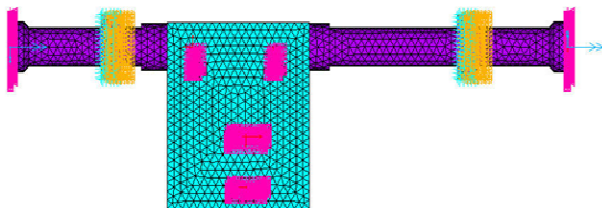
Three Dimensional geometry with allowable design space was created by using CATIA as shown in Fig.1.



**Fig. 1. CAD Model of differential**

### 2.3 FE Modeling

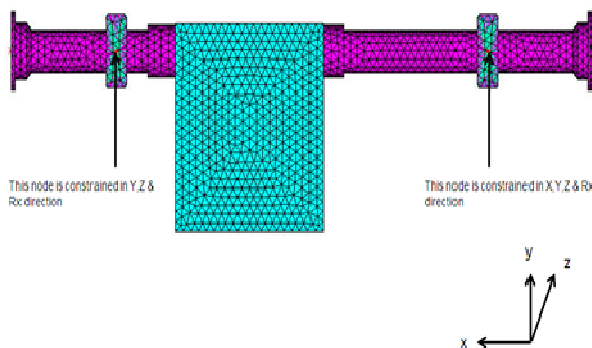
Mesh was created by using ANSYS. Care was taken while defining design & non design area. 10 noded tetrahedron elements are used for meshing. Fig.2 shows FE Model of differential



**Fig. 2. FE Model of differential**

### 2.4 Boundary conditions

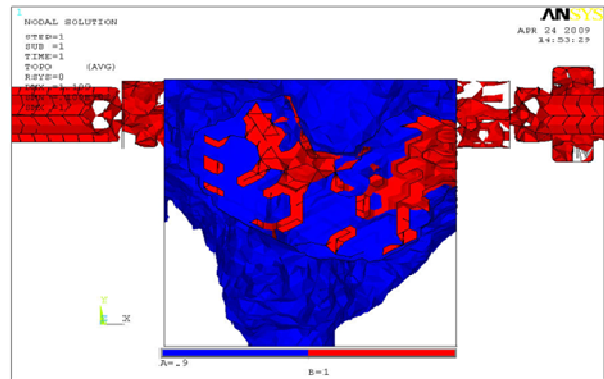
The adopted boundary conditions are shown in Fig.3. The boundary conditions are adopted so that the model will not move rigidly in any direction.



**Fig. 3. FE Model of differential**

### 2.5 Topological optimization

The topological optimization was carried out by using ANSYS & modified shape is obtained as shown in Fig.4. The objective was to minimize the compliance subjected to volume constraint



**Fig. 4. Optimization output**

### 3) Completed Work

Creating CAD model of a various components of gear box in AutoCAD 2006

- 1) Measuring the dimensions of the existing gear box:

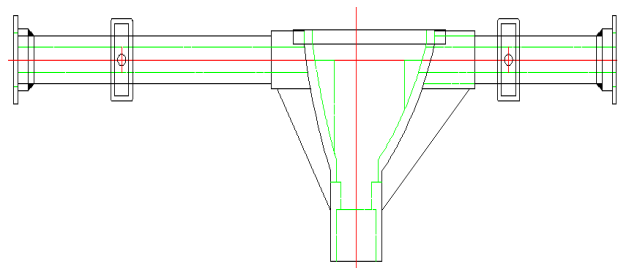
This step involves measurement of the dimension of the existing gear box. Vernier Caliper, Scale, Micrometer & depth gauge etc. are required for measurement of the gear box. Reverse engineering tools are used to measure some critical dimension of gear box.

- 2) Creating CAD model of a various components of gear box

Modelling of various components in AutoCAD 2006

#### A) Model of Housing:

The housing is made up of the cast iron material. The purpose of the housing is to provide casing for pinion, crown wheel, bevel pinions & differential gear & cage

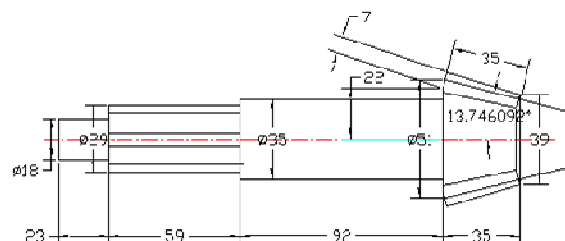


**Fig. 5. Model of housing**

#### B) Pinion :

This is made integral with shaft & is overhang from two tapered roller bearing mounted back to back (small ends of the roller pointing inwards). These are spaced apart by their outer races or cups which are located against shoulders in pinion housing. The bearing cups are pressed into the

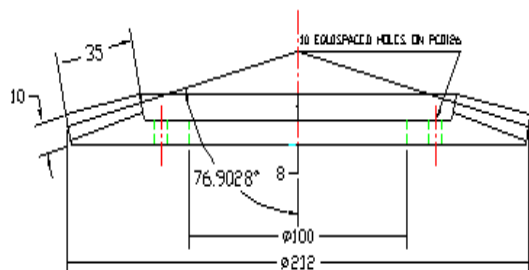
pinion housing. The fit between cone & bearing inner race is interference fit. The spacing between the pinion bearings is generally 2.5 times of the overhang distance the material of the pinion is alloy steel. The number of teeth on pinion is 11. Module of pinion is 4.5mm. The teeth are spiral. The helix angle is 30.



**Fig. 6. Dimensions of pinion**

### *c) Crown Wheel*

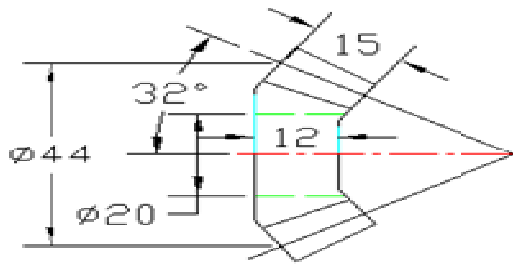
This is bolted behind its mesh to provide a slip resistant joint with flanged differential cage, which is in turn carried by two tapered roller bearing mounted face to face (small end of tapered roller bearing pointing outwards). On each side of differential cage bosses are machined to locate bearing cones, these made an interference fit on their seating



**Fig. 7. Crown wheel dimensions**

#### *d) Model of pinion gear*

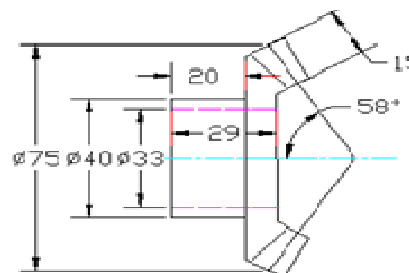
The number of teeth 10. Module of pinion is 4.5mm. The teeth are straight bevel type. Facewidth =15 mm



**Fig. 8. Pinion gear dimensions**

***e) Model of differential bevel gear***

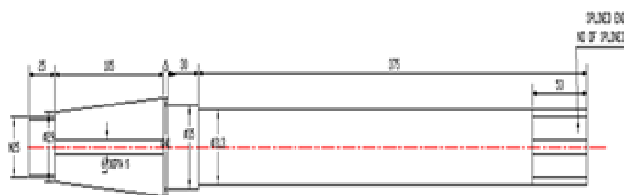
The number of teeth 16. Module of pinion is 4.5mm. The teeth are straight bevel type. Facewidth = 15 mm



**Fig. 9. Differential bevel gear dimensions**

*f) Axle*

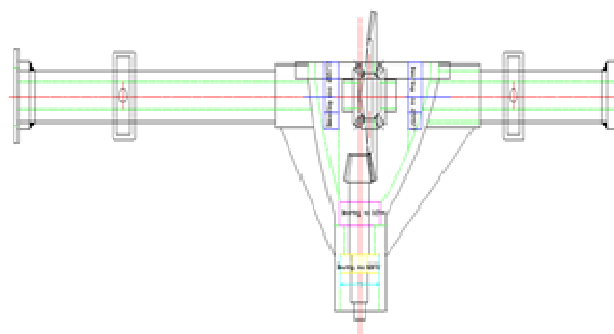
The axle is made up of alloy steel



**Fig. 10. Axle dimensions**

***g) Assembly of differential gear box & its components in AutoCAD***

All the components viz pinion, crown wheel, bevel gears, differential gears, axle are assembled .These are required to find out the bearing reactions

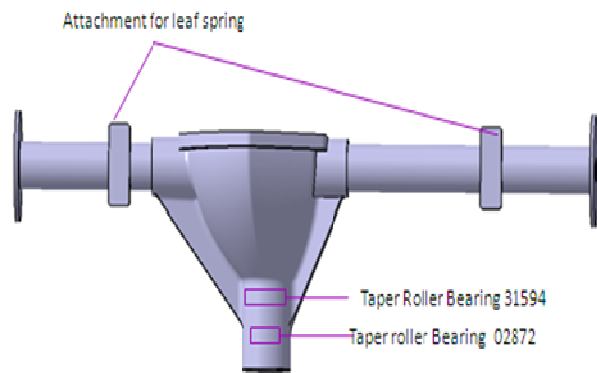


**Fig. 11. Assembly of differential gear box**

### 3. CREATING 3 D MODEL USING CATIA V5 R16

*a) Front view of housing –*

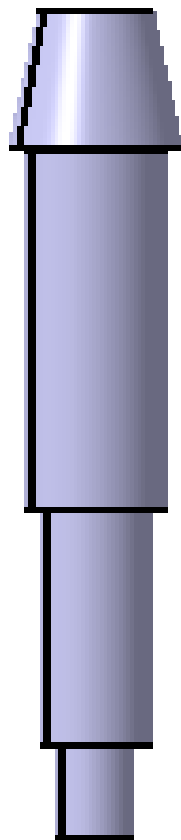
The housing is modelled in part design. This model is used in ANSYS software for analysis. The major commands used are pad, pocket, stiffener, Multisession solid, plane selection etc.



**Fig. 12. Front view of housing**

**b) Solid Model of pinion**

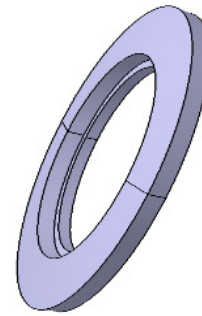
The major command used for doing solid pinion model is shaft



**Fig. 13. Pinion**

**c) Solid model of crown gear**

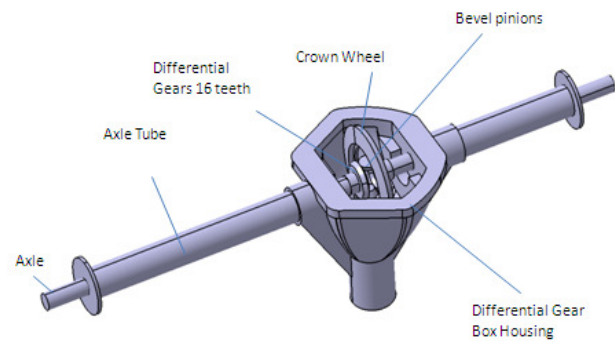
The major commend used for doing solid crown gear model is shaft.



**Fig. 14. Crown gear**

**d) Assembly of housing**

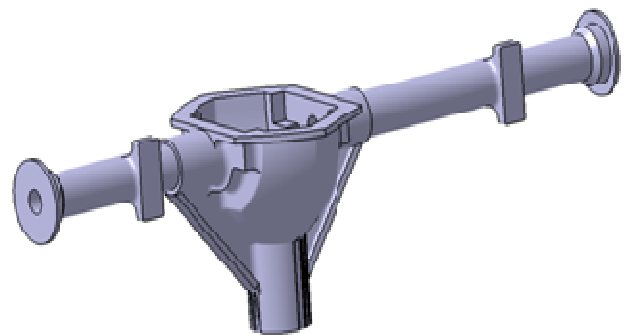
Assembly of all parts is done in assembly design module



**Fig 15.. Assembly of housing**

**2.6 Optimized CAD model**

Fig.15 shows the Optimized CAD model of differential



**Fig. 16. 3D Optimized CAD Model**

**4. CONCLUSION**

The weight of an optimized model (i.e. new design) is reduced by 22.63%.

**5. RESULTS**

Table 2 shows the comparison of the different parameters

**TABLE 2: Comparison of result**

		Displacement(mm)		von Mises Stress(MPa)	
		Original Model	Optimized Model	Original Model	Optimized Model
Case 1	Torque load + Vertical reaction + Traction	100%	Increased by 3%	100%	Reduced by 28.42%
Case 2	Torque load + Vertical reaction + Braking	100%	Reduced by 5.86%	100%	Reduced by 15.05%
Case 3	Torque load + Vertical reaction +Cornering (Left)	100%	Increased by 3.5%	100%	Reduced by 23.30%
Case 4	Torque load + Vertical reaction +Cornering (Right)	100%	Reduced by 7.03%	100%	Reduced by 11.01%

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# Formation of Metal Deposits on Fuel Injector and its Effect on Performance of the Engine: A Review

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**Abstract:** Fuel injection is the system for supplying high pressurized fuel to maximum mixing of fuel with air in an internal combustion engine. Fuel injector directly injects fuel into direct fuel injection system to perform quick combustion. In actual practices, no engine is completely efficient. There are lot of theories on why deposits are formed, one of them is due to incomplete combustion of fuel, deposits are formed on nozzle, fuel injector, valves, cylinder which leads to excessive smoke emission, loss of power, poor fuel efficiency, excessive noise, hot spots in combustion chamber (knocking). This is not just a problem of Audi, Mercedes Benz, Volkswagen, BMW issues this is the problem of all direct injected vehicles. This review paper gives the information about formation of deposits, how to prevent it and what we can do if we face the problem of metal deposits.

**Keywords:** fuel injector, Nozzle, carbon deposits, soot formation, NOx emission, engine.

## 1. INTRODUCTION

Fuel injection system is the introduction of fuel in an IC engine by the use of an injector. Petrol engines can use gasoline direct injection, where the fuel is directly delivered into the combustion chamber, or indirect injection where the fuel is mixed with air before the intake stroke. Diesel engine uses direct injection in which the diesel is injected directly into the cylinder filled with compressed air. Primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel through a small nozzle under high pressure, while a carburetor relies on suction created by intake air accelerated through a Venturi tube to draw the fuel into the airstream.

### *Requirements of Fuel Injection System*

1. The fuel injection should occur at correct moment during every cycle of engine.
2. It should supply the fuel in correct quantity as required by varying engine loads. If more than one cylinders are used having separate fuel injector, they should supply equal amount of fuel to each cylinder.
3. The injected fuel must be broken into very fine droplets, so that proper air-fuel mixing will be takes place.
4. The spray pattern should ensure rapid mixing of fuel and air in combustion chamber.

### *1.1 Types of Injection Systems*

Injection systems basically are divided in 2 types a) Air injection system b) Solid injection system.

- 1) **Air Injection System:** This system is also known as air blast injection. In this, fuel is forced into the cylinder by means of compressed air. This system is very few times universally at present, because it requires a multistage air compressor, which increases engine weight and reduces the brake power. This method is capable of producing better atomization and penetration of fuel resulting in higher brake mean effective pressure. The perforated disk atomizer came into use about the year 1900. In 1908, Knut Hesselman of Sweden disclosed an air aspirating valve atomizer which became popular for small injection engines. The early Krupp engines used single stage air compressor till the invention of three stage compressor which was introduced on engines by Diesel Motor Company of America. Steam for fuel injection was attempted by Thornycroft of England in 1903, but failed because of the exhaust temperature was not high enough to develop steam pressure for injection.

- 2) **Solid Injection System:** One of the first satisfactory airless injection systems were applied on an engine in 1910 by James McKechnie of Vickers, Ltd. of England. In solid injection, the liquid fuel is injected without the aid of compressed air. Every solid injection system must have a pressuring unit i.e. pump and an atomizing unit i.e. the injector.

### *1.2 Fuel Injector*

A well designed fuel injector insures quick and complete combustion of fuel. By atomizing the fuel into very fine droplets, it increases the surface area of droplets resulting in better mixing and subsequent combustion. Atomization is



done by forcing the fuel through a small orifice under high pressure.

An injector assembly consists of a needle valve, compression springs, nozzle, an injector body. One of the important parts of fuel injector is nozzle which is used for atomization, distribution of fuel to required area, no dribbling, non impingement on walls. There are different types of nozzle that are single-hole nozzle, multi-hole nozzle, pintle nozzle, pintaux nozzle.

Operation of fuel injector: Fuel is injected by a pump. The pump exerts sufficient pressure that lifts the nozzle valve. When the nozzle valve is lifted up due to pressure, fuel is spread evenly into the combustion chamber at the end of the compression stroke. As the fuel supply is stopped, the spring pushes the valve back to its initial position. The fuel pressure must be greater than the compression pressure, the system need high fuel jet speed to atomize droplets small enough for rapid evaporation.

### 1.3 Soot Formation in Diesel Engine

IC engine produces soot as a result of incomplete combustion. Soot formation occurs mainly in diesel engine rather than gasoline engines because of the way that fuel is injected and ignited. The air fuel mixture in diesel is of heterogeneous type, which do not mix properly which creates fuel dense pockets that produces soot when ignited. Majority of the soot get easily escape through the exhaust port, some gets pass the piston ring, and ends up in oil.

Factors that causes soot formation:

1. Worn piston ring
2. Rich air- fuel ratio
3. Periods of excessive idling
4. Injectors with poor spray patterns

Clogged air filters decreasing air supply, which increases fuel air ratio leads to increased soot formation.

Soot particles are 98% carbon by weight and typically spherical in shape around .03microns in size. High soot conditions can lead to carbon deposits in piston ring groove which causes degradation of oil seal between piston ring and cylinder liner causing abrasion. Excessive soot level in oil is commonly known as Sludge, leads to reduced lubrication due to impeded oil flow through engine as well as oil filters causes increase in engine wear sometimes leads to premature engine failure.

When we shut our engine off, there is small amount of air fuel mixture in combustion chamber which will settle on back side of valves overtimes will harden and built up carbon deposits that will cause misfire during cold weather and decrease fuel economy ^[1]. This we can minimize by

using high grade fuel. Some time sodium hydroxide will get deposited on internal injector from sodium source ^[7].

## 2. LITERATURE SURVEY

OrhanAltin and SemihEser [1], studied about the petroleum fuels (gasoline, diesel, jet fuel) degradation can cause engine failure, engine malfunction, affects engine performance. Molecular components of fuel determine physical properties, engine performance, thermal stability. Thermal stability is measured in terms of fuel's tendency to form deposits on fuel lines. Poor stability of fuel leads to maintenance problem, high maintenance cost. Carbons deposits are formed in 2 different ways a) metal catalysis-decomposition route b) non-catalytic/ thermal-polymerization route, may affect the heat transfer in system. Injectors are highly sensitive to small amount of deposits where fuel is metered, this reduces fuel flow, increases emissions, poor fuel economy, loss of power.

Prakash C Jena and Snehal S Jadhav [2], studied about the biodiesel blends B10 and B20 obtained from mixture of mahua and simarouba oil. It was observed that B10 blends gave best running performance with lower NOx emission and reduced soot deposits because of complete combustion of fuel due to availability of extra oxygen in biodiesel molecules. But the emission of CO and HC were higher for B10 blends. For B20 blends, there was 40% reduction in carbon deposition compared to HSD.

B.H.Lee [3], studied the effect of no. of fuel injector of holes which is one of the factor for controlling rate of fuel and air mixture. Multiple injections have been used to reduce particulate emissions. Increased mixture of fuel and air during ignition delay period increases the rate of combustion and NOx emission.

GollapudiArunManohar [5], studied about the Electronic control unit which is compatible for both 2 stroke and 4 stroke engine, slotted opto-coupler is used for sensing the rotational speed of crank shaft. By varying the resistance of monostablemultivibrator, pulse width of injection timing can be controlled.

Jacqueline Reid [7], studied about the internal injector deposits from sodium sources like sodium hydroxide. In the JFTOT (Jet Fuel Thermal Oxidation Test) testing, the addition of DDSA (Dodecenylsuccinic acid) to fuel containing a soluble sodium source produced a clear effect on deposit type and location. The corresponding tests with mono-acid lubricity improver did not show such effect. HFRR testing has showed that adding fuel soluble sodium source with mono-acid lubricity improver additive, did not result in loss of lubricity performance. The same mono-acid in combination with NaOH exhibited a complete loss of lubricity performance.

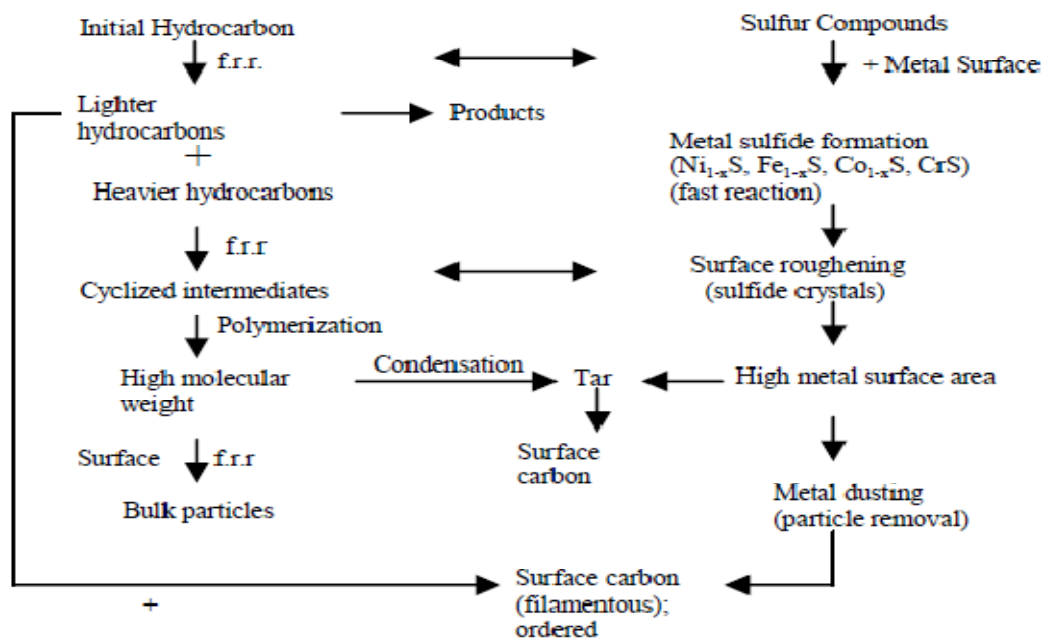
Hongming Xu [8], studied the fuel injector deposits in direct-injection spark ignition engines which can be reduced by adding detergents o chemistry and dosage rate. Improvement in injector design i.e. outward opening piezo-driven injector with good surface finish and counter bore design can be beneficial in preventing formation of injector deposits. Insulating and cooling the injector tip reduces injector deposit in some conditions

H.M.Patel [9], studied the use of biodiesel to optimize fuel injection system. Biodiesel blend have lower brake thermal efficiency than diesel which reduces CO, HC and smoke emissions. He proposed that injector tip temperature and fuel composition are root causes of deposit formation. For High Pressure DISI, deposits on injector tip, orifice reduces

fuel flow affecting spray cone angle, droplet size leads to cause combustion instability with increased emissions and fuel consumption. For Air Assist DISI, coking in DISI injector were dependent on temperature. As temperature increases, the deposits get increased which affects the spray shape.

### 3. EFFECTS OF METAL DEPOSIT ON PERFORMANCE OF ENGINE

The process of metal deposit like carbon and sulphur deposition form hydrocarbon, sulphur compounds, metal surface is shown in figure 1. Metal deposits on fuel injector results in reduced performance of engine which are explained below.



**Fig. 1. Carbon deposition mechanism including sulphur metal surface involvement.**

1. Soot formation and carbon are main cause of wear on parts of engine like fuel injector, intake valve, port, combustion chamber.
  2. Brake specific fuel consumption (BSFC) increases with increase in proportion of biodiesel in fuel blend results in increased exhaust gas temperature.
  3. Sodium deposit formed on internal injector results in rough idling, power loss, high emissions, high pressure fuel pump wear injector sticking internal component corrosion, engine failure.
  4. PCV (Positive crankcase ventilation) system sometimes blamed for leaving oily film on intake valve which turned out to form carbon.
  5. Fuel degradation can cause engine failure, engine malfunction, increased maintenance cost.
  6. Injector carbon deposit causes operational problem like reduced fuel flow, excessive smoke, excessive noise, degrading driveability, decreased fuel economy.
- #### 4. CONCLUSIONS
- The conclusions of this discussion are as follows:
- During Gasoline fuel, use insulating materials on area of injector exposed to combustion chamber to reduce deposits. For Diesel fuel, add detergent type additives which can re-dissolve deposit that are already formed

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- During Gasoline fuel, use insulating materials on area of injector exposed to combustion chamber to reduce deposits. For Diesel fuel, add detergent type additives which can re-dissolve deposit that are already formed

and reduce formation of deposits by stabilizing the deposit precursors.

- Jet fuels used in aircrafts play important role as propellant and coolant, it should have high thermal stability, so that carbon deposition can be minimized which may not result in disrupted spray pattern, hot spots formation in combustion chamber (knocking) which will be helpful for smooth running of engine.
- Biodiesel plays important role in improving its lubricity due to presence of long chain molecule, degree of instauration, oxygenated moist. Exhaust gas temperature increases with increase in engine load due to increased the concentration of biodiesel leads to higher NO_x emission.
- Fuel composition play important role in injector deposit formation. High olefin content have high reactive unsaturated carbon bond leads to increase the tendency to form injector deposit. High sulphur content also increases the injector formation problem.
- EGR (Exhaust Gas Recirculation) helps to reduce emission of NO_x, Extra inert exhaust gas having no O₂ molecule with not help for combustion process, it will reduce the temperature by absorbing heat.

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# Effect of Biodiesel on Tribological Properties of Lubricating Oil in CI Engine: A Review

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**Abstract:** For long –term implementation of biodiesel in transportation engine, lubrication is necessary for proper functioning of the engine. Application of Biodiesel in engine affects lubricating properties of engine oil ultimately may cause wear to the corresponding parts like cylinder liner, piston, valves and injectors. Therefore it is necessary to study the effects of Biodiesel on lubricating properties of engine oil. Current paper reviewed different studies associated with the effect of biodiesel on the engine oil. Many studies are carried out using different blends of various methyl esters prepared from different feed-stocks. Researchers reported changes in density, viscosity, flash/fire point, ash content, carbon deposits, copper corrosion, carbon residue. All these properties of lubricating oil are significantly affected by the blending ratio of the methyl ester and neat diesel. In addition the physiochemical properties of the oils from the different feedstock plays an important role in analysing different properties of lubricating oil.

**Keywords:** Biodiesel, methyl esters, tribology, lubrication, lubricating oil.

## 1. INTRODUCTION

Biodiesel is considered as the most readily available renewable alternative to mineral diesel at present stage of technology development, which still remains the most-widely used transportation fuel. Biodiesel can be produced from renewable feed-stock such as edible and nonedible oils, vegetable oils, wasted frying oils or animal fats. It is non- toxic, oxygenated Sulphur free, bio-degradable and renewable fuel.

Vegetable oils have approximately 90% heat content of petroleum diesel. Also their combustion related properties are comparable to petroleum diesel. But several properties of oil such as high molecular weight, high viscosity and low volatility, etc. cause poor fuel atomization which can lead to incomplete combustion which can result in severe engine deposits, piston ring sticking, injector coking, lubricating oil degradation, etc. Many of these problems are a result of high viscosity, polyunsaturated and low volatility character of vegetable oils. Therefore it has to be converted to more engine-friendly fuel called Biodiesel. The blending of biodiesel is the dilution of oil in pure petroleum diesel. B00

resembles pure diesel, B10 resembles 10% vegetable oil and 90% diesel. Similarly B20 is 20% oil and 80% diesel by volume.

### 1.1 Trans-esterification Process:

Biodiesel is produced by trans-esterification of vegetable oils and animal fats with alcohol in the presence of a catalyst (Sodium or Potassium hydroxide). In this process triacyl glycerides, of which most fats and oils are composed, are reacted with ethanol or methanol mono alkyl esters (biodiesel) and glycerol, a by product. The resulting fuel is either termed as methyl ester or ethyl ester, depending on the alcohol used in the reaction, methanol or ethanol, respectively. After the reaction, residual glycerin, catalyst, alcohols, and free fatty acids are removed from the finished fuel as they get directly mixed with the engine lubricant through fuel dilution, and indirectly through the formation of combustion products (soot) and gases which may get dissolved in the oil. Fuel dilution normally occurs when liquid fuel impinges on the cylinder walls, mixes with the lubricants and then slowly accumulates in the oil sump.

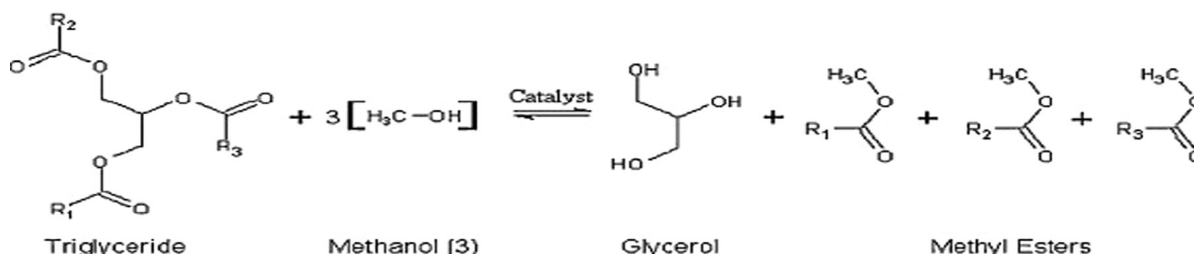


Fig. 1. Chemical reaction of the trans-esterification process. [ N. A. Zainala, 2017]

### 1.2 Tribology:

Tribology is a science which deals with the interactions between the two moving bodies or surfaces in relative motion. It is mostly associated with friction, corrosion, wear-lubricity, engine life, etc. As lot of energy is wasted due to these phenomenon. Hence, it is essential to minimize and eliminate the losses incurred due to friction and wear. [Bhushan B. (2013)]

### 1.3 Lubrication:

In order to overcome and reduce friction between mating parts, lubrication is applied. A lubricant is interjected between the two relatively moving bodies. Friction could be increased when inappropriate lubrication is provided or not effective lubrication film is formed.[ F. Sundus et al., (2017)]

### 1.4 Physicochemical Properties of Lubricants:

1. Viscosity: Viscosity is a measure of the substance's resistance to flow and it corresponds to the informal concept of 'thickness'. High Viscosity means the substance has high resistance to flow and Low viscosity means Low Resistance to flow and vice-versa
2. Viscosity index(VI): Viscosity index is a measure of the change in the substance's viscosity with the change in temperature. A high Viscosity Index indicates a small variation in the viscosity with respect to a change in temperature and vice-versa.
3. Flash Point: Flash point refers to lowest temperature at which lubricant must be heated before it vaporizes. This property is used to determine the volatility of a lubricant.
4. Ash content: Ash is the non-combustible part of the fuel/lubricating oil. It can be either present as solid or oil/water-soluble metallic compounds. These solid particles are often called as sediments.[ Atul Dhar and Agarwal (2014)]
5. Carbon residue: Polymerisation of lubricating oil leads to increased content of non-combustible polymerized part of higher molecular weight base-stock remains as carbon residue after combustion/pyrolysis of the lubricating oil.[ Atul Dhar and Agarwal (2014)]
6. Oxidation stability : Oxidation stability of a lubricant indicates its ability to withstand oxidation. The rate of oxidation of lubricants is affected by several factors such as temperature, pressure and the presence of water and contaminants also.[ N. A. Zainala, 2017]
7. Copper Corrosion: It is the corrosiveness of lubricating oil to the copper containing engine components.[Atul Dhar and Agarwal (2014)]

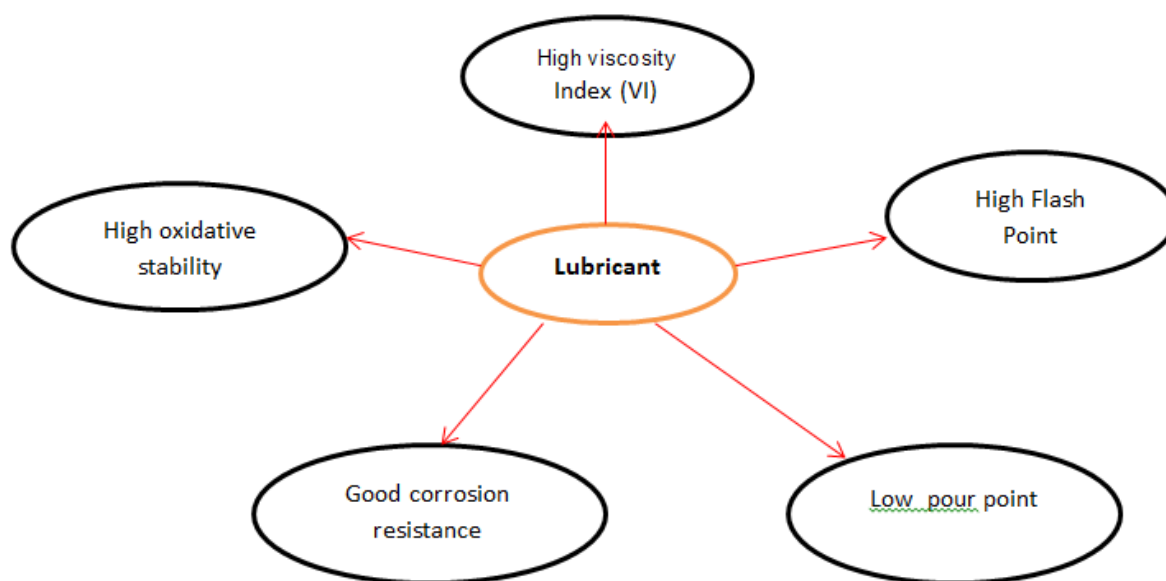


Fig. 2. Properties of good Lubricant.[ N. A. Zainala, 2017]

## 2. LITERATURE SURVEY

Atul Dhar and Agarwal (2014), investigated the effect of 20% biodiesel blend (B20) of linseed oil methyl ester on the tribological properties of lubricating oil in 512 h endurance test. In this paper, he reported that by measuring viscosity and flash point, the fuel dilution was lower for the lubricating oil from the biodiesel fuelled engine in comparison to diesel fuelled engine.[8]

Atul Dhar and Agarwal (2014) studied the effect of 20% Karanja biodiesel blend on tribology of lubricating oil in comparison with mineral diesel in a 200h long endurance test. In his paper he concluded that for biodiesel fuelled lubricating oil, higher increase in density, ash content, carbon residue was observed compared to diesel fuelled engine. Higher ash content in biodiesel fuelled engine was due to higher wear trace metals. No difference in copper corrosion potential was observed.[ Atul Dhar and Agarwal (2014)]

S. H. Hamdan et al., (2017), studied the tribological impact on engine lubricants SAE10W40 and SAE5W40. The dilution of PME(palm oil methyl ester ) was done by using Pin-On-Disc tribometer. He concluded that the acceptable PME dilution threshold level for SAE10W40 was between 28.0-vol% & 34.5-vol%, and for SAE5W40 was upto 17.5-vol%. He also stated that by increasing the dilution level

beyond threshold level, tribological properties which are not desirable could be attained which could lead to introducing significant material wear which might lead to failure of machine element.[ S. H. Hamdan et al., (2017)]

Dairene et al (2010), studied the effect of different B20 fuels on Lab-Aged engine oil properties. Three types of B20 fuels were used, Original SME B20, Degraded SME B20, and LME B20. The oil used was SAE15W40. Oil Aging was performed on Ford Oil Aging Test(FOAT). He concluded that, no differences was observed in film formation, friction and degree of wear from different B20 sources. Compared to original SME fuel, Degraded SME did not caused higher wear in High Frequency Reciprocating Rig (HFRR) test. [Dairene et al (2010)]

Shailendra and Kumar(2010), studied effect of Rice bran oil Biodiesel on lubricating oil degradation and wear by performing an endurance test on CIDI engine Mahindra & Mahindra Model MDI-3000. He concluded that for 20% Biodiesel (B20) blend, less carbon deposits on in-cylinder parts were observed. Except Big end bearing, all the other vital parts showed less wear for B20 Fuelled engine. Less wear on piston ring was observed for B20 blend. Pb and Al were found slightly higher for B20 fueled engine, which might be due to the attack of biodiesel on paints and bearings.[ Shailendra and Kumar(2010)]

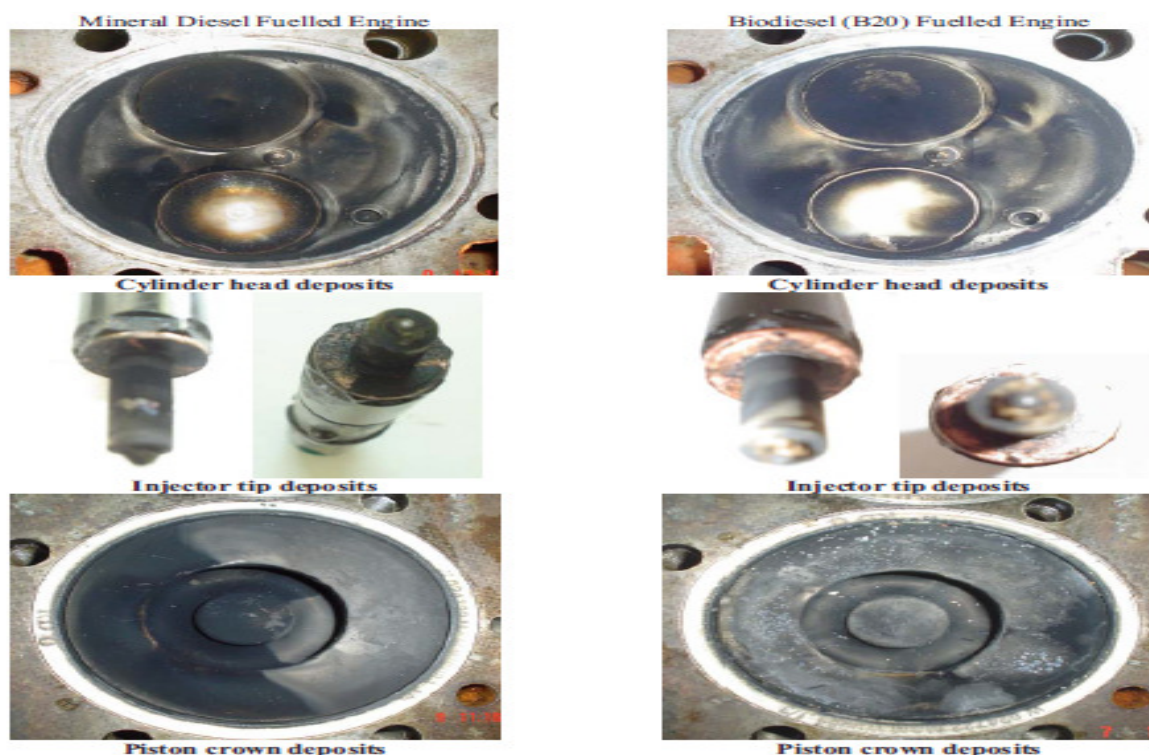


Fig. 3. Carbon deposits on vital engine parts[Shailendra and Kumar(2010)]

Ambesh et al., (2013), studied the effect of Jatropha Biodiesel fuelled engine on tribological properties of Lubricating oil for 30h endurance test. He concluded that viscosity, Flash/Fire point of lubricating oil was found to be increased with usage in diesel and lower increase was observed with biodiesel. Viscosity (40°C) of used oil was higher in diesel fuelled engine, but it was higher for B20 fuelled engine at 100°C. He also concluded that jatropha biodiesel can be used in combination of petroleum diesel for existing diesel engines without any significant modification in the engine.[ Ambesh et al., (2013), ]

A.K. Agarwal et al., (2012) studied the effect of 10% karanja oil blend on wear of various engine components and lubricating properties in comparison with baseline mineral diesel. He concluded that carbon deposits on various vital parts was found slightly higher for K10 fuelled engine and traces of corrosion on piston and cylinder head was also observed. Viscosity, density and ash content was comparable with baseline diesel. No difference was observed in copper corrosion behavior with base mineral diesel.[ A.K. Agarwal et al., (2012)]

Milan Tomic et al., (2014), investigated the use of biodiesel obtained from sunflower to improve lubricating properties of low sulphur fossil diesel. He concluded that lubrication properties were improved by adding biodiesel in low sulphur fossil diesel. By adding 1% vol /vol helped in achieving lubricating properties in accordance with the standard EN590.[ Milan Tomic et al., (2014)]

Jianbo Hu et al., (2005) studied lubrication properties of biodiesel for to use as a lubricity enhancer. Unrefined and refined biodiesels derived from vegetable oil were made and added to mineral diesel. He concluded that unrefined Biodiesel showed higher lubricity properties than refined biodiesel. Fatty acid methyl ester were the main composition affecting lubricity properties of biodiesel and triglycerides had almost no effects.[ Jianbo Hu et al., (2005)].

F. Sundus et al., (2017) studied the tribology with biodiesel in enhancing biodiesel stability and fuel properties. He concluded that for a short term usage, biodiesel reduces wear and friction but for a long term use, the wear and friction is as same as diesel. Due to hygroscopic nature of biodiesel, it gets corrosive nature.[ F. Sundus et al., (2017)]

### 3. CONCLUSIONS

The conclusions of this discussion are as follows:

1. Density, ash content and carbon residue of biodiesel fuelled lubricating oil increases more compared with baseline diesel fuelled engine.

2. There is no noticeable difference in copper corrosion potential of biodiesel fuelled engine and mineral diesel fuelled engine.
3. The level of dilution of Vegetable oil plays an important role in lubrication. Dilution beyond or before threshold level can give less desirable tribological properties which can lead to machine element failure.
4. For short term usage, biodiesel decreases wear and friction. But for long term usage of biodiesel, its wear and friction is almost same as that of mineral diesel.

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# Computational and Experimental Analysis of Nonlinear Dynamic Motion of Reciprocating Vibro Separator

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**Abstract:** In this paper, Model of reciprocating vibro separator is prepared on CREO parametric software further it is analyze on ANSYS software. The motion of reciprocating vibro separator model & experiment is observed by Poincare, Fast Fourier Transit (FFT) & Time data graphs. The computational modal of reciprocating vibro separator is observed for different material property & validated for particular elasticity. The experimental data indicated that the vibro separator is having elliptical motion with periodic motion. Also motion behavior of reciprocating vibro separator is observed & concluded that the experiment is matching with computational model. The motor angle of vibro separator is varies from 25 degree to 35 degree for constant motor speed at 1000 rpm.

**Keywords:** Motion analysis, Model validation, Material property

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## 1. INTRODUCTION

Generally any product is not available in pure form. There is always some impurities are there in required final product to remove that impurities vibro separator is used as separating machine. The machine has vast area of application like food industries, Minerals, Paper mill, mining, agro industries etc. This can work for both solid and liquid type raw material for separating material. The reciprocating vibro separator is separating the final product & impurities by using basic vibration motion. Like the motion of shacking the separator box will give the output. The Reciprocating Vibro Separator is made based on how much amplitude is required to achieve desired output product.

Lala Zhao, Yuemin Zhao, Chunyong Bao, Qinfu Hou, Aibing Yu (2016) have noticed that the average velocities of simulations with both spherical and non-spherical particle models in each case show similar trends with the tests. For most cases, the velocities of spherical particles are more highly over-predicted than those of non-spherical particles because of the simplification of particle shapes. Changlong Du, Kuidong Gao, Jianping Li, and Hao Jiang(2014) have used the Separator which has unbalanced mass rotor at center & after that they said that by analysing the screening process of three different vibration screens, it proves that the variable linear vibration screen has better power distribution and screen surface movement the flexible screen surface can increase the amplitude of the screen surface and reduce the material blocking phenomenon. The screen experiment results of the two style screen surface vibration screens show the huge advantage of flexible screen surface than fixed screen surface in screen efficiency and avoiding material crush and it also

provides a powerful proof to verify the correctness of the simulation work. Xiaohao Li, Mingxu Ma (2014) The research results which carried out in the paper showed that, about the nonlinear vibration system which supported by the soft nonlinear characteristics spring, the amplitude value of the nonlinear system can be automatically compensated when the vibrating mass of the vibrating system fluctuating in small-scope, which make the amplitude approximate remaining constant. ZHAO Lala, LIU Chusheng, YAN Junxia (2010) indicate that The amplitude and the vibration direction angle have a great effect on the particle average velocity and the average throw height considered over the normal range of linear screen parameters. The vibration frequency and the inclination angle of the screen plate have a small influence. To obtain the ideal sieving effect for materials that are difficult to sieve the frequency and amplitude of vibration, the inclination angle of the screen plate and the vibration direction angle should be chosen as 13 Hz, 6.6 mm, 6° and 40°, respectively. Monica Soldinge (2002) has use the monte carlo simulation to check the effect of angle between base line & separator box bottom layer line, then he conclude that for the  $\beta$  value of 5 degree the rpm speed is range from 1000 to 800. Liu Chusheng, Wang Hong a, Zhao Yuemin, Zhao Lala, Dong Hailin (2011) have tried to get the optimum angle between base line & separator box bottom layer line  $\beta$  & conclude that the increment of screen deck has a same effect on banana screening process as inclination of discharge end And when the values of inclination of discharge and increment of screen deck inclination are 10 degree to 5 degree the banana screening process get a good screening performance in the simulation

Dong Hailin, Liu Chusheng, Zhao Yuemin, Zhao Lala (2013) they studied on linear, circular & elliptical motion

of screen they said that travel velocity of the particles during linear screening is the fastest. This results in a thin material layer but the lowest Overall screening efficiency. The circular mode gives the lowest particle velocity along the screen but the highest screening efficiency. In this case, the material layer is thick but the interaction between particles and the penetration effect are enhanced.

Vladimir A. Golovanevskiy, Vasily A. Arsenteyev, Iliya I. Blekhman, Vladislav B. Vasilkov, Yuliy I. Azbel, Kira S. Yakimova (2011) says that the description of specific vibration-induced phenomena presented in this paper provides the basis for development of materials handling technologies and process equipment to affect bulk material flow behaviour with vibration. To ensure the highest vibration-aided bulk granular material separation efficiency, it is suggested that the amplitude and frequency of vibration should be selected on the basis of providing the vibration overloading factor  $w$  values of  $w \approx 3$  or slightly higher. Further research needs to focus on the development of an overall model describing behaviour of granular material under vibration. Lijun Wang, Zhenjun Ding, Shuang Meng, Huijun Zhao, Huiqiang Song (2017) For a particle on the screen moving from the front to the back of the screen, the regimes of the different particle behaviors such as stable periodic motion, period-doubling bifurcation motion, bifurcation motion, and the chaotic motion, were obtained. Chaotic motion was found to be beneficial in separating particles effectively from other agricultural threshed materials and avoids at the same time particles accumulating on the screen and enhances the probability that the particle penetrates the screen hole. A detailed investigation on this aspect (passage rate) was not performed and remained open problems. J. LI, C. WEBB, S. S. PANDIELLA and G. M. CAMPBELL (2002) concluded that For a screening system involving granular materials, it has demonstrated that the critical feeding rate or bed depth for the most effective screening operation can be determined via conducting the DEM simulation. Further work will focus on the implementation of advanced experimental techniques to measure the process and to validate the model. HE Xiao-mei, LIU Chu-sheng (2009) have Studied on vibro separator & told that the motion of vibro separator is following the elliptical trace. A theoretical kinematic analysis of the vibrating screen was done to study how varying different parameters affects the motion of the screen. Kinematics parameters of the vibrating screen that motion traces are linear, circular or elliptical are obtained. Their work also conclude that the position of the exciter axle center relative to the center of gravity of the vibrating screen is extremely important for screening efficient Thus; we can design a vibrating screen with higher processing capacity without increasing power consumption by adjusting the relative position of the axle center. Zhao Yue-min, Liu Chu-sheng, He Xiao-mei, Zhang Cheng-yong, Wang Yi-bin, Ren Zi-ting (2009) says that the

dynamic response analysis shows that adding stiffening angle and longitudinal stiffeners to both side plates is able to decrease transverse deformation of side plate and ameliorate the twist deformation of screen frame. The maximum transverse displacement of the vibrating screen is 0.13 mm.

The present work is to investigate the dynamic motion behavior of Reciprocating vibro separator by using ANSYS software besides using DEM simulation method. In the past, The set up for experimental work is done on the placement of motor at the up side center place of vibro separator box whereas in present work the motor is connected at two side center place of separator box.

## 2. COMPUTATIONAL MODEL & ANALYSIS

The reciprocating vibro separator has different parts which are modeled out in CRE-O 3.0 Software and the analysis is done on ANSYS 14.5. Main part of Reciprocating Vibro separator are Motor, Connecting plate, Rubber pad, Separator box, Unbalanced mass. The parts with their Dimensions are made in CRE-O software. Based on half power bandwidth equation value the damping ratio is calculated. For the rubber pad the damping ratio is as Natural frequency is 0.0017.

As discussed earlier in this paper the dynamic motion behavior of vibro separator is observed. Taking different input parameters like motor angle ( $\alpha$ ), motor speed & properties of Foundation rubber as varying parameters the dynamic motion behavior of vibro separator is observed. In the setup of reciprocating vibro separator angle between motor axis & vertical line of separator box is taken as  $\alpha$  and Angle between position of separator box & base line is taken as  $\beta$ .

## 3. EXPERIMENTAL WORK

The experimental work is performed at GAJANAND industries at UNJHA. The setup was prepared as per the computational work. Here the two vibro motors are running at 1000 rpm. The variation in motor speed is  $\pm 20$  rpm. Each vibro motor is having 0.5 Hp power. The Experimental Setup is running in between 980 to 1020 rpm motor speed with 30 degree motor angle. Here the separator box has two motor connected at two side wall at the middle point of separator box height. Four unbalanced masses are connected to each motor, which has weight of 3.34 kg each. The experimental result are taken at 3 point. one point is at the top center place of vibro separator box and remaining two points are at top side end position of separator box as shown in figure 2.a. The piezoelectric accelerometers sensor (uni-axial) is used for picking up the vibration signals from the point on separator box. These special piezoelectric pickup type sensor is used with a frequency of range from 1-10kHz. The sensitivity of sensor 107 mV/(m/s²) with integral electronics piezoelectric

accelerometer (IEPE) input mode of sensor. The analyzer used to measure the acceleration data is made by Crystal Corporation. The modal of analyzer is CoCo-80 as shown in figure 2.b

#### 4. RESULT & DISCUSSION

In this Figure 5(a-b) are shows that the value of acceleration in horizontal direction is nearly doubled than in vertical direction. Figure 5(c-d) are the FFT plot that indicate that the motion is periodic with no vibration

we also observe that from Acceleration figure 6(a-b) that experiment acceleration value for the vertical direction should be lower than horizontal direction to get the required output. By plotting the graph for different elasticity of foundation rubber in as shown in figure 6(a-b) we observed that in vertical & horizontal direction the elasticity of 25 MPa for foundation rubber has the acceleration value in vertical direction is less & in horizontal direction acceleration value is more.

#### 5. CONCLUSION

In present work the dynamic motion behavior is observed for horizontal and vertical direction using dynamic analyzer.

1. From Experimental Figure 5(a-b) it is clearly indicated that the acceleration value should be more in Horizontal direction. The acceleration value must be lower in vertical direction compare to horizontal direction.
2. Figure 6 (a-b) shows that the rubber pad with 25 MPa elasticity having the same acceleration pattern as experimental work.

The current work shows that the vibro separator can be used for multi-purpose products in many fields. As the different sizes products can be separated by different rate of vibration and the vibration rate can be changed from different elasticity of rubber.

#### ACKNOWLEDGEMENT

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# Cooling and Cleaning Mechanism of PV Module: An Overview

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**Abstract:** Renewable energy sources are pollution free, available in infinite amount and eco friendly in nature. Therefore development of non conventional energy industry has become present need of society. Among the various sources of non convectional energy, solar energy plays most important role. The device which converts solar radiation into electrical power is called solar panel. Because of dust accumulation and high temperature PV module subjected to short temperature losses like loss in efficiency and long term loss like permanent damage. Therefore, cooling and cleaning is most important to avoid this loss and to increase the performance of PV modules. Solar cell efficiency drops at the rate of 0.4 - 0.5% once the temperature excided STC. The dust accumulation of  $4\text{g/m}^2$ , reduce the power conversion by 40%. In this paper various methodologies for cleaning and cooling are studied to know the effect of those methods on PV panel to raise the performance, efficiency and power.

**Keyword:** PV module, Efficiency, Cooling and cleaning of PV module, Dust accumulation.

## 1. INTRODUCTION

Renewable energy resources have potential to meet present demand of energy for world. One of the most promising renewable energy technologies is PV (photovoltaic) technology. Most of the PV cells are silicon semiconductor junction devices. This technology develops rapidly in both developed and developing countries (Tiwari G. and Dubey S., 2010). Term “Photovoltaic” formed by merging two terms- “photo”, means light, and “voltaic” means electricity. India has about 300 clear and sunny days in a year. Figure 1 shows the average solar distribution in India. The calculated solar energy reaches to Indian land is about 5000 trillion kilowatt-hours (5 EWh/hr) (Muneer T. *et al.*, 2005). Although large on earth, solar energy for producing electricity is use in little quantity. This problem causes from factors such as low efficiency of module in energy conversion. The electrical characteristics of PV module can be changed due to inherent and external factors. Inherent factors are mainly due to manufacturing process and the material used for PV cell and external factors such as environmental factors, dust type, location and installation factors.

The cleaning and cooling can be done with various means as natural, mechanical, self-cleaning Nano-film, electrostatic means, water sprinkling and phase change material.

### 1.1 Factors affecting the performance of PV panel

Performance of PV panel is affected due to various factors such as climate condition, dust properties, PV array, glazing

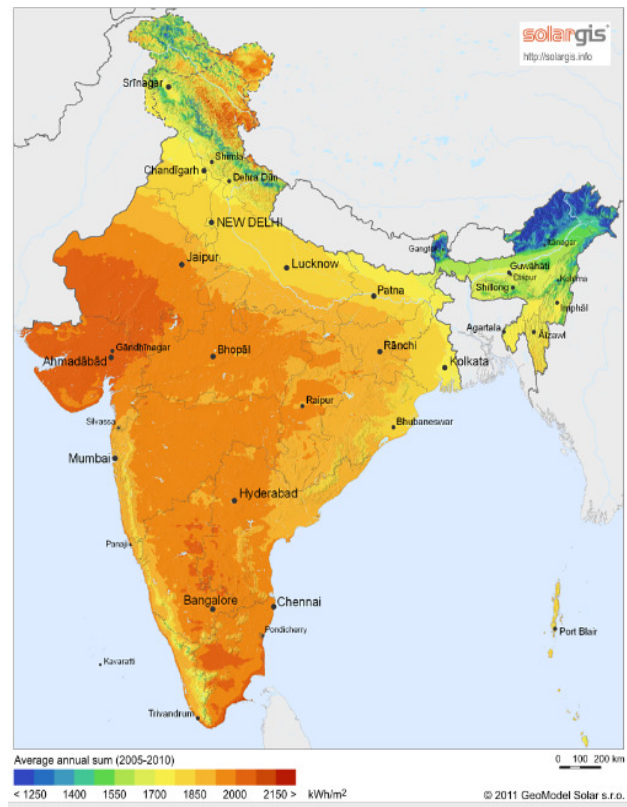
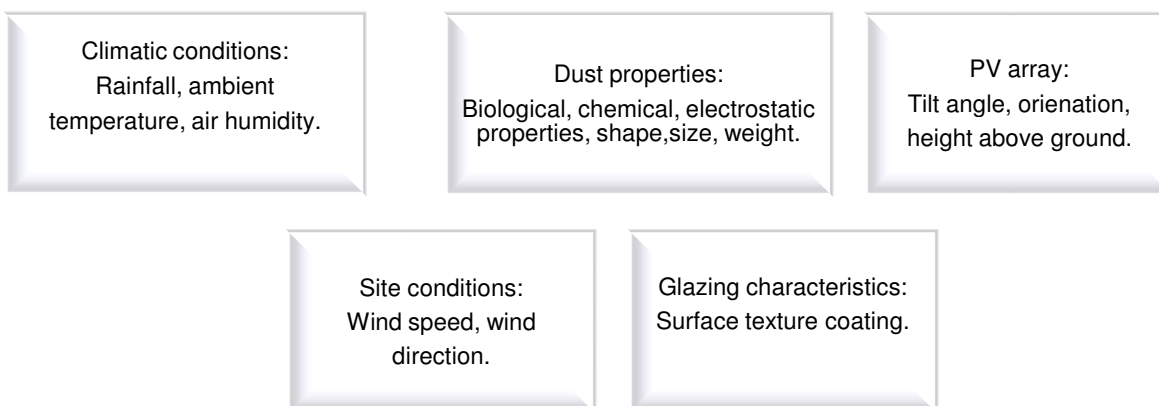


Fig. 1. Average solar irradiance in India.  
(Muneer T., RSER-2005)

characteristics etc, brief discussion about those factors are as given below.



**Fig. 2. Factors affecting performance of PV panel (W. Herrmann et al., 2015)**

### 1.1.1 Climate conditions

Because of the effect of sun angle on climate most tropical area is hot. Due to geographical variations in some areas of India large scale monsoons, winter is found. At 25 °c temperature of uncooled module reaches to 60 °c and cooled module reaches to 45 °c at same atmospheric condition for a sunny day. The maximum difference of 13.26°c is measured. Cooled module produces 3.63% more electrical energy (Meyer E. and Busiso M., 2011). In test condition, starting from 25 °c without cooling the PV panel generates 62wh and after using flow rate of 2L/min the panel produces the power around 77Wh. which is gain in 24%. And the efficiency increases by near about 16%. Different rate of water is to be flowed on panel i.e. 1 lit/min, 2 lit/min, 3 lit/min, 4 lit/min and it was shown that water flow at the rate of 2 lit/min generates more power than other flow rate (Matias C. *et al.*, 2016).

### 1.1.2 Dust properties

Dust generally consists of fine particles of matter in the atmosphere that comes from various sources such as pollution, soil etc. we may classify dust as domestic dust, atmospheric dust coal dust. Data of 17 days without rain period of Portland is taken and found that particle deposition of 0.85 g/m² tends to reduction of power output about 4% lower than normally clean panel. When the test is expanded up to 28 days it is observed that power output reduced by 6% (Smith M. *et al.*, 2013). Smaller particles settle more easily on PV panel than larger panel (this observation is not for round dust particle). Another important result- smooth 'sphere' with only 20 µm diameter shows larger adhesive forces than the dust particle which having diameter more than 60 µm (Moutinho H. *et al.*, 2017).

### 1.1.3 Glazing characteristics

Glazing is a term which is derived from the word 'glass. Glazing can be done on surface of window or door and also

in PV modules. Glazing is commonly use in low temperature solar thermal collector for retain the collector heat. Coating reduces the light reflection and increases light transmission. Self cleaning Nano films are made up of super hydraulic material such as TiO₂. Coating carried out in two stages, 1st photo catalytic reacts under ultrasonic light and distributes organic dirt. 2nd because of hydrophobicity water is distributed over the total surface clean the dust. The effect of this film is like lotus plant show high hydrophobicity and very low wet ability. Nano-structure increases contact angle as high as 150 degree therefore water droplets quickly pass away taking dust and particle (Gaofa H. *et al.*, 2011)

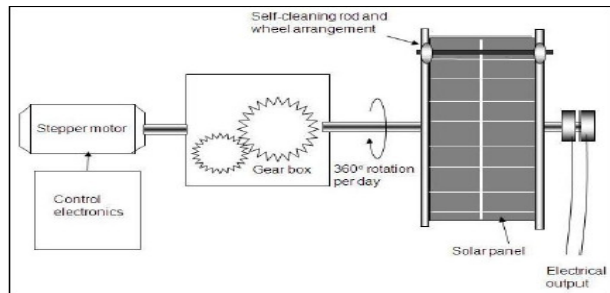
### 1.1.4 PV array

Different sites having different tilt angle varies from 10-70 degrees. Angle equal to latitude of that site gets maximum amount of insolation. It is observed that in summer incident insolation is highest for surface which having inclination 10-15 degree less than latitude and at the time of winter 10-15 degree higher than latitude (Tiwari G. and Dubey S., 2010).

## 2. LITERATURE REVIEW OF SOLAR PANEL CLEANING AND COOLING

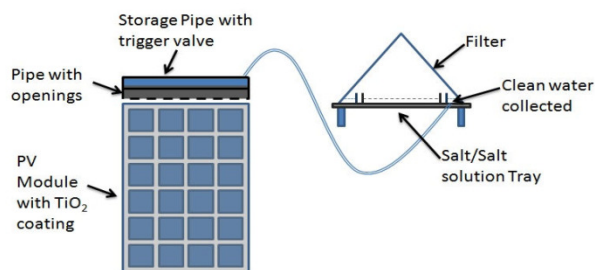
Presently PV modules are cleaned and cooled by various techniques like natural, manual, mechanical, electrostatics, sprinkling of water, self cleaning Nano-film, fins, phase change materials etc. Basically cooling can be done by two ways; - Active cooling and passive cooling. Active method consumes energy, it is based on air or water cooling hence pump or fan is needed for fluid circulation. It generally used in situation where increasing efficiency of panel is greater than the energy needed to power the system. Passive cooling does not consume electricity and basically cooling is done by passive air, water. Water cooling is more efficient because of higher thermal capacity of water.

Ravi Tejjwani *et al* (2010) they proposed a sun tracking automated cleaning system. To track the sun, the panel is made such that it rotate  $360^\circ$  angle in a day. The module starts its rotation from vertical position at the time of sun rise and rotates  $15^\circ$  per hours facing towards east. When panel comes in vertical position (6AM & 6PM) the brush fitted in rod slides on panel from upward to downward direction due to gravity and cleans a panel twice a day.



**Fig. 3. Mechanism of panel rotation**

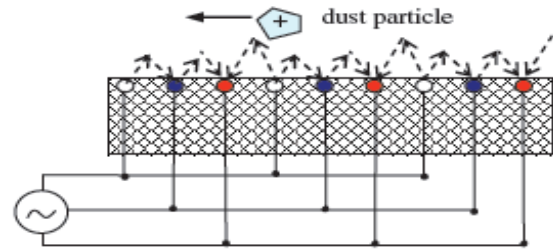
Jim Joseph John *et al.* (2013) proposed cleaning system using ambient moisture and self cleaning coating, the process is carried out in two stages, 1st stage absorb moisture from ambient and separate water from solution. 2nd stage, the water which is collected is allowed to flow from self cleaning coating. The salt tray which absorbs moisture placed in atmosphere in late evening to early morning so that salt absorbs moisture. From morning to evening salt solution is heated due to solar radiations results in formation of vapors which condense on glass surface to form water droplets. When sufficient water is collected within a channel inside a filter over sufficient period of time trigger switch mechanism allow water to flow from the pipe.  $\text{TiO}_2$  coating is used to increase the spread ability of water on the module.



**Fig. 4. PV module cleaning mechanism**

Gaofa He, *et al.* (2011), proposed an electrostatic technique for dust removal. Charge and uncharged dust attract to the module if there is high potential on surface of solar panels because of electrostatic forces. Electric curtains consist of series of parallel electrodes attached to the dielectric which transmit oscillation in electrode potential. Electrode which is connected to single phase AC voltage can form standing wave field this field is only oscillate the particle but not

able to travel them from module. Due to this reason electrodes are connected to multiple AC voltage which oscillate and travels the dust particle along the surface following electrical field under correct frequency and amplitude.



**Fig. 5. Three-phase electrical curtains**

Calebe Abrenhosa Matias *et al.* (2016) proposed the reused water flow at ambient temperature to increase the efficiency by decreasing operating temperature. They perform experiment in closed room without any interruption of climatic condition. The set up consist of The set of devices used to cool the PV panel consist of a luminaries' capable of transferring solar radiation, a water tank, which send water through gravity. a 140W photovoltaic panel; temperaturesensors to measure the atmospheric and the module temperature;a flow sensor for checking the amount of water transfers tothe PV panel; a valve for controlling the water flow; a MPPT device to extract the maximum power supplied by the panel joined with a communication device, which will collect all the data and will supply it to a computer via serial link RS-232.

Edson L. Meyer and Mtunzi Busiso (2011) aim to compare the efficiency, daily electrical energy generation and thermal response of cooled and uncooled module. They use two modules one module is directly water cooled and another is cooled naturally. Perspex box container have storage tank for both cold and hot water. Cold water flow on panel and hot water goes back due to buoyancy and cooled in container, this process is continue till sun is available.

### 3. IDENTIFICATION OF PROBLEM IN PV MODULES

Tejjwani R. *et al.*, (2010) proposed that, dust situated on front surface of module block the incident radiations from the sun. Due to this power output reduces near about 50% if the module is unclean for a month in tropical nations like India. Larger dust particle having higher cross section area, are more easily removed by wind whereas hurricane-forces not able to remove dust particle smaller than  $50 \mu\text{m}$ .

Smith M. *et al.*, (2013) states that particle situated on PV panel does not affect largely on the temperature of PV panel. But power losses due to dust deposition are high for the period of 28 days in Portland.user seen power loss up to



6%. Removal of 0.85 g/m² of soiling improves the power output of panel up to 3.8% was observed.

Matias C. *et al.*, (2016) increase in the operating temperature of the PV panel tends to reduction in open circuit voltage (*V_{oc}*) and a slight increase in short circuit current (*I_{sc}*), therefore there is a loss of power and loss of power conversion efficiency ( $\eta$ ). As per standard testing condition power output of PV panel at 45 °C drop near about 10 %.

Edson L. Mayor & Mtunzi Busiso, (2011) observed that at 25 °C, temperature of uncooled module reaches to 60 °C and cooled module reaches to 45 °C at same atmospheric condition for a sunny day. The maximum difference of 13.26 °C is measured. Cooled module produces 3.63% more electrical energy.

#### 4. DISCUSSION

From detail literature review it is found that, the surface of PV panel required to be cleaned and cooled regularly for efficient performance. Accumulation of dust particles and increase in temperature reduces the power output. Few months of exposed of unclean module result in power loss up to 25-50%. Researcher venture to reduce the cost of PV modules, but almost saturation is reached. The next option is reducing the power loss. Research publication focus cost comparison based on manufacturing of cooling and cleaning system. Cooling and cleaning by water requires big tanks for water storage, some methodologies required multiphase AC voltage to accelerate and move charge dust, cleaning with moisture needed adequate amount of moisture. Discussion about various techniques such as manual, mechanical, water sprinkle, Nano-film, electrostatic mean and phase change material was done and check their respective cost, effect on output parameters and efficiency.

#### 5. CONCLUSION

Sun have plenty of radiation to produce electrical power. About 5000 trillion kw-hrs solar energy reach to Indian land. At present, the population is mostly depending on non renewable sources of energy such as fossil fuels, coal, oil and natural gases for power generation. As more this resources decreases automatically prices will increase. To overcome this, PV panels can use to generate electrical power.

Paper highlights the effect of environmental factors, dust type and installation factors on PV modules efficiencies. Present work clearly indicated that the increase in dust accumulation and rise in temperature decreases the efficiency of PV module. Again we find out what temperature PV module needed, tilt angle for different locations, need and effect of cleaning to increase the power output.

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# An Overview of Concentrate Oil Cake Pallet Making Machine for Cattle Feed

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**Abstract:** In spite of the constant growth in milk production in India throughout the last 70 years, the position as the world's largest producer of milk is not achieved, the fact remains that the productivity (yield) of cattle is very low and is one of the lowest in the whole world. Likewise, in spite of the largest cattle population in the world, the per-farmer holding of cattle is very low at the level of about 2-3 animals and lack of attention toward food which results in depletion in the quantity of milk. The objective of this work is to study the processes and pallet machines that are available in the market for manufacturing of concentrate pallet for the animals. Oil cakes are the principle building block of most of the tissue and its basic feature is its good source of protein that enhances cattle nourishment.

**Keywords:** concentrate oil cake, pallet machine, cattle, oil cake, pallet.

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## 1. INTRODUCTION

Food is the basic need of every living being; similarly feed for cattle's is also very important and necessary as well. A good nutritive meal increases the productivity and growth of an animal and without proper meal no one can survive. Thus, the requirement of good cattle feed always exists and it will further increase with the increase in population of cattle's. State and Central Govt. are concentrating on incremental increase of cattle's in the state / country.

These cattle's provide self-employment to the beneficiary by generating sufficient income through their produce or flash. For better growth concern require good feeding material on an average each milking animal require about 3-5 kg of cattle feed per day. Thus, each and every district has huge requirement of cattle feed.

Existing cattle feed machines and mixers are very much costly and so they can only be used for large scale production. There is no as such machine that can fulfill the needs at small scale level. Hence we are developing the machine that can fulfill the needs of oil cake at small scale level. This machine will be easy to operate, mix all the ingredients properly and will produce an oil cake that will be rich in proteins.

## 2. LITERATURE REVIEW

Nutritive value of commonly available feed and fodder in India, animal nutrition group Amrita Patel. (2012); have documented out from all over country regarding the feed provide and its various characteristics that help in guiding the nation regarding animal health and nourishment. They found out the basic available fodder available as well as studied out what is lacking even though there is such a

program carried out. The productivity of the milk and cattle health is the main priority that can lead India becoming largest supplier of milk chain in the world. The specification of all the ingredients is given so that the suitable amount of feed can be circulated. The classification is done on the basis of the concentrate which is available from plant source, grain and seed source, molasses, roots and tubers, protein source (oilcakes), roughages (dry, green), grasses etc. The unconventional source of feed is also available that can be beneficial to the cattle that is provided. [Amrita Patel. (2012)]

V.K.Karangiya et al., (2016) have found that the supply balanced feed block is provided to maintain the health and nourishment in the urban areas due to its size and nutritive value. This densified complete feed blocks are made from the crop residue having different combinations like chopped roughage and soaked concentrate mixed. The complete feed block machine is used to make a block that contains all the ingredients that make the block more nutritious. This machine is powered by 7.5 to 15 HP electric motor, its working pressure is 6000 psi and the capacity of the machine is 30-40 blocks per hr. The roughage part and concentrated parts are the basic raw material of the machine which is then added by salts, minerals for the better results. The advantage is far more in concern of the less feed wastage and complete care is taken regarding cattle food. As the economical factor is taken into consideration; this machine can qualify it very well. [V.K.Karangiya et al., (2016)]

Sumitra Ramachandran et al., (2006) have found the applications of the oil cake because of its qualities that it is rich in protein and which is considered as food supplements. Oil cake has very much to the biotechnological application



regarding the production of enzymes using various oil cake which is substrate in solid state fermentation (SSF), production of antibiotics and bio-pesticides which contains high proportion of carbon and lead to greater significance in pharmaceutical firms, production of bio-chemicals like sesaminol and glucoside and sesaminol diglucoside. As a growth supplements for nematodes using linseed oil cake agar, mustard oil cake agar, neem oil cake agar, emerson agar and YPSS agar for growing endoparasite and nematodes, as feed source to the cattle due to its high protein content so as to increase milk contain, as energy source, as biocontrol agents. This applications are environmental friendly and are bi products that are very useful. [Sumitra Ramachandran et al., (2006)]

O.A.Olugboji et al (2015) have designed and tested the poultry (fish) feed machine which includes the hopper, barrel, palletizing die, suitable bearing, belt, conveyor belt. The two horse power motor was used as a driving mechanism. The working of the machine is done by using raw material toasted soya beans, wheat offal, palm kernel which is then hammered out followed by milling. The material is then passed through the screw type mixer in which the material is extruded properly then the pallets are to be formed are compacted through temperature rising from 80-100 degree Celsius the steam is used as a binder agent thus the material through flow is cooled and desired output formed. The power required to run the machine is calculated out as 2237.8 W. The capacity of the machine is calculated to be 5kg/h .this machine is solving problem in the small scale enterprise and can boast to the food production of poultry and fish production. [O.A.Olugboji et al (2015)]

Kishan et al., (2016) have observed the effect on environment by excess use of fossil fuel. The use of biomass like saw dust, dry leaves, coffee husk, rice husk can be done in preparing biomass briquette that lead as an alternative source of fossil fuel. The paper deals with design and fabrication of low cost briquette machine which having grinding unit, carrier unit, compressing unit. The working is raw material feed in the hopper are grinded and the then collected in rectangular box which is then slides outward this grind material is filled in the cylinder where hydraulic jack piston help to move upward and compress all the grind material producing briquette. This briquette are high calorific driven object, when the calorific value was obtained of sample consisting of dry leaves, sawdust and starch as binder lead to calorific value 4856.17 kcal/kg was little higher value to other industrial samples. This machine helps in creating best to waste and provide a way to reduce the use of fossil fuel. [Kishan et al., (2016)]

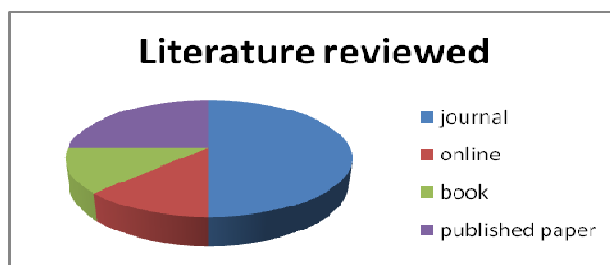
Animal husbandry, feed management (2009-15) of TamilNadu Agriculture University has compared the feed management of the cattle as per the age, approximate body weight and requirement for the high milk output. The

recommended concentrate charts are plotted out in which the dairy farmer can understand what amount of portion to be given at a certain age group so as to keep the cattle healthy and produce good amount of milk. For example; a concentrate mixture data and schedule to be feed are given that are ground cake 32 parts (kg), gingili 5 parts (kg), rice bran parts 25 (kg), dried tapioca chips 35 part (kg), mineral mixture 2 part (kg), salt 1 part (kg) are which is given from 4 days to 24 weeks as per situation. The data produce is helpful in scheduling the feeding of cattle and taking into consideration various factor that affect the cattle's life cycle. [TamilNadu Agricultural University]

A group of researcher including Md. Ahiduzzaman and Islam (2013) found that the electricity consumption for the biomass briquette production process is very high. To counter that; biomass stove has been made to replace the rising of the temperature in the electric heater. The electricity consumed is about 200 to 250 kWh for 100kg/hr briquette and by applying stove it can be used to save 35% of total electricity. Screw extrusion process is carried out which helps in heating the biomass and to obtain the required shape. The stove is made of refractory brick and clay. The electricity consumption was drastically reduced to 79.33 kWh/tonne. The significant reduction in the electrical consumption is an advantageous process to be carried out. [Md. Ahiduzzaman and Islam (2013)]

Gabriel et al., (2015) have studied and calculated the shape of the blade in the concrete mixer truck. The construction of the blade is so that the mixing of the ingredient is done homogenously and the material in the each section is properly blended. The helix type of blades is generally used as the lateral surface to be examined out and symmetry to be formed in the due course of action. The calculation are able to get a proper understanding of the unfolded lateral surface and blade under area in plane which is carried on the Turbo Pascal 7.0 are significantly not fully able to discovered as the limitation to all the theoretical computational relations. The partial settlement is found that to replace arcs of circle in such way that to fulfill its adequate point of arc is less than 1 mm. [Gabriel et al., (2015)]

### 3. RESEARCH GAP

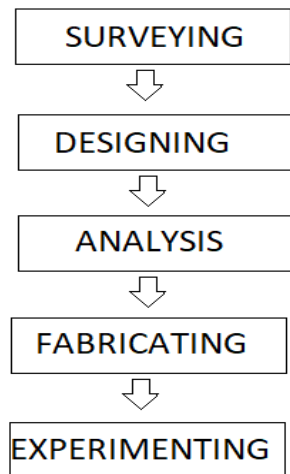


**Fig. 1. Pie chart showing the details of referred Literature work**

Reviewing the review paper from (2008-2016) there been a greater short coming gathered. The traditional method of cattle feed is insufficient to achieve desire nourishments that should be given on the regular basis. The protein enrich diet in a single source medium is lacking. Health and milk production is the main objective related to cattle husbandry but it is not able to get noticed; thus causing insufficient in the growth of species. The floor area used by the current existing machine is large approximately 10*10 feet. Due to lack of availability of manpower, sufficient work output is not produced. The consumption of power is very high up to 15 HP. The healthy reproductively growth is also affecting.

#### 4. METHODOLOGY

The goal of the paper is to propose an extension of the existing study conducted in the above articles and to provide a suitable approach to it. The new schema of the process is presented in Fig. 2



**Fig. 2. Process Planning flow chart**

The first goal is to properly understand the current market scenario by carrying out a survey and primarily focusing the farmers, machine buyer and seller and veterinary doctor. The data collected is able to make new definition; that allows providing alternative solution for existing techniques and will able to extent the reviewed subject. The designing of the machine will lead to new aspect regarding the machine inability of the cattle feed, proper mixing and to obtain a pallet of desired size and shape.

The second goal is to fabricate the model that has been thoroughly analyzed using suitable material grade and dimension. The inspection is then carried out using various parameters that will fulfill the generated need.

#### 5. CONCLUSION

The proposed approach represents an extension to have a proper understanding of the different aspect of the present cattle feed making machine as well as the different methods

of feeding which is done by farmer. Furthermore the review article studied able to understand various aspects that have to be taken in consideration regarding the health and milk productivity. The parameters that were studied will definitely provide the basic idea associated with oil cakes and currently available cattle feed machine. Upon successful completion of this project, small scale enterprise and farmers will be directly benefited, design and fabrication of the machine will lead to easy to operate and will mix all the ingredients properly and will produce a cattle feed that will be rich in nutrition value.

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# Review on Biomass Briquetting Process

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**Abstract:** The objective of this paper is to study the biomass briquetting process and look overview on various techniques and research developed in this field. A brief literature review on various aspects of biomass briquetting process is carried out. Piston press and screw extrusion are generally used briquetting technologies out of which screw extrusion is more significant from commercial point of view. The effects of different compaction characteristics like particle size, moisture, temperature of biomass and die, pressure and additives need to be studied for variety of biomass available in regional areas. The optimum process condition on cost and economic basis may vary place to place.

**Keywords:** Biomass, Briquettes, Renewable Energy, Biofuel.

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## 1. INTRODUCTION TO BIOMASS BRIQUETTING

A biomass briquette is a compressed block or a cake of biomass substances like rice husk, sawdust, wood chips and charcoal etc. which is combustible and can be used as a biofuel. Basically it is made up of organic materials of agricultural wastes like rice husk, groundnut shells, bagasse and other agricultural residues, etc. Burning of biomass briquettes is having less emission of green house gases like CO₂ as compared to burning of coal, since carbon percentage is less in it. The low carbon energy is the need of our globe now, because global warming and climate changes. If briquetting technology developed for economical and efficient ways, it will save a considerable cost of coal extraction and pollution control in agricultural based countries like India. So It is important to study more and more options and materials of biomass for harnessing the maximum amount of energy from it.

The use of handmade cow dung briquettes in rural areas of India is common from very early period. It was also recorded in Nepal before many years. Even though it is inefficient energy source, enough heat for cooking purposes and keeping warm is provided by it. The major problem of using biomass directly along with low efficiency is wide spread pollution. The conversion efficiencies are as low as 40% with particulate emissions in the flue gases in excess of 3000 mg/Nm³. Briquetting could help to reduce this pollution to a acceptable level. The first commercial production plant was created in 1982 and produced almost 900 metric tons of biomass. From 1984, more factories were set up, after the improvement in briquetting process based on efficiency. In 1925, Japan independently started developing technology to harness the energy from sawdust briquettes, known as "Ogalite", which was widely spread in other Asian countries as well as European countries. Europe and the United States have developed the reciprocating ram/piston press while Japan has independently invented

and developed the screw press technology. Although both technologies have their merits and demerits, the screw pressed briquettes are more superior to the ram pressed solid briquettes in terms of their storability and combustibility.

## 2. LITERATURE ON BIOMASS BRIQUETTING

A brief literature review was carried out on current research in this field of biomass briquetting and previous work done. The various factors like properties of biomass used, binder material, effect of compression pressure, raw material particle size, production cost, energy consumption and energy gained, different pre-treatment processes, influence of additives, methodologies used for drying and combustion, biomass conversion and applications were analysed by researchers.

I. E. Smith et. al (1977) conducted tests which demonstrate that wheat straw can be compressed to a relative density greater than unity, and stabilized at that density without binding or other mechanical aids. Their experiments concluded that by applying heat and pressure volume of loose biomass can be reduced to great extent which is beneficial for easy transportation. The total energy input to the process is only about 6% of the calorific value of the material. M. O. Faborode and J. R. O'callaghan (1987) used a compression ratio model, for optimization of Compression/Briquetting of Fibrous Agricultural Materials. Optimum hold times of 5 and 2.5 s, respectively, were identified for long and ground straw. The optimum initial charge density for ground straw in a 53 mm die is 104 kg/m³. Based on the findings of the study, a four-stage compaction process, which reflects the inertia and elastic phases of compression, is proposed. Arun K. Tripathi, et.al (1998) made an assessment of the availability of agricultural residues as raw materials for biomass gasification and briquetting in India with consideration to

their seasonal and geographical availability dimensions. An attempt to estimate the costs of agricultural residues has also been made. The potential availability of eight selected agricultural residues (Arhar stalk, maize stalk, maize cobs, cotton stalk, mustard stalk, jute and mesta sticks, rice husk and groundnut shells) has been assessed. It is estimated that more than eight million tonnes of these residues will be produced in the year 2000-2001 with a primary energy potential of about 1200 Peta Joules. Cost per unit tone of agricultural residue was identified and found much lower as compared to coal in India. A. Demirbas (1999) demonstrated that waste paper and wheat straw or their mixtures can be compressed to a relative density greater than unity and stabilized at that density without binder material. A reduction in the volume of the material also provides its technological benefit, i.e., the material could be transported and stored more economically than is possible at present. The optimum moisture contents and briquetting pressures were found to be, respectively, 18% and 780 MPa for waste paper, 22% and 710 MPa for wheat straw and 18% and 750 MPa for a 20%(w) waste paper-straw mixture. The effect of the temperature on the briquette density of wheat straw was determined. The best wheat straw briquettes were obtained at 385 K.

K. Sivakumar et. al (2012) carried out performance analysis on briquetting biomass with different size in 10 kW down draft gasifier and concluded that briquetting of bio mass materials saw dust and cow dung having a ratio of 75:25 have significant heating value and performance in the down draft biomass gasifier. Jitthep Prasityousila and Akarawit Muenjinab (2013) determined the optimum mixing ratio for solid fuel briquettes produced by extrusion of rejected material of municipal waste composting char (MWCC) and sawdust char (SC). and concluded that a MWCC to SC ratio of 20:80 with 20% slop waste was most suitable for production of solid fuel briquettes. The study demonstrated that the rejected material of municipal waste composting can be used as an alternative fuel for industrial use. This will not only promote the reuse of waste material for optimal benefit, but will also reduce the use of landfill space. Mariusz J. Stolarski et. al (2013) investigated the quality and cost of small-scale production of briquettes, made from agricultural and forest biomass in north-eastern Poland. The experiment involved production of eight types of briquettes. Briquettes made from pine sawdust were of the highest quality. The briquette production cost ranged from 66.55 € t⁻¹ to 137.87 € t⁻¹ for rape straw briquettes and for those made from a mixture of rape straw and rapeseed oilcake (50:50), respectively. In general, briquette production was profitable, except for the briquettes made from a straw and rapeseed oilcake mixture. Teodora Deac et. al (2013) studied the pollutant emissions impact upon environment by combustion of sawdust briquettes in thermal energy. In terms of the NO emissions the peak values in all cases were recorded at the maximum

temperature of combustion gases, respectively for 30 mm length briquettes (Fuel 1: 261ppm; Fuel 2: 214ppm; Fuel 3: 231 ppm). Reducing of NO emission can be achieved by increasing of briquettes length.

Chatcharin Sakkampang et. al (2014) investigated the feasibility of using the mixture of glycerin and biomass as an alternative fuel by measuring the energy used in the densification process and the energy gained from the briquette fuels. The results obtained by them showed that the energy consumptions were 1–3% of the energy gained for the domestic-scale solar drying condition, and 12–18% of the energy gained for the industrial-scale condition. In addition, the optimum ratio of glycerin mixed with biomass was 30% by mass. They have concluded that the mixture of glycerin and biomass was considered feasible to be further developed as an alternative fuel. M.G. Montiano et. al (2014) used, partial briquetting as a means of biomass densification to allow for biomass inclusion in coking coal blends. With respect to coke reactivity it would be possible to add up to 15 wt.% of briquettes without impairing coke quality. N.S.L. Srivastava (2014) analyzed briquettes made from vegetable market waste SPRERI showed that the vegetable market wastes can be converted into good quality briquettes. The bulk den-sities for VMW briquettes increased substantially to 509 - 747 k g/ m³ from initial bulk densities of 4 4.2 to 60 kg/ m³ of dried and loose vegetable market waste. The calorific values of different VMW briquettes were in the range of 10.26 - 16.60 MJ/ kg. The cost of VMW briquettes, including the cost of raw material, was between \$ 24.68 and 28.90 per tone is comparable to the cost of wood available at market rate. Zhiwei Wang et. al (2015) proposed a mathematical model for a synthesized evaluation according to theories of grey relational analysis (GRA) and the analytic hierarchy process (AHP). This model was used to select a biomass briquette fuel (BBF) system scheme considering hierarchies of economy, cleanliness and environmental protection, production capacity, product quality, and production stability, along with 20 other indices, including capital investment, dust content, drying capability, briquette rate, and the machine repair cycle. The researchers concluded that the major machines used in a large-scale BBF system drying, chopping, briquetting, and cooling were combined reasonably and optimized, providing a more integrated technological solution as well as a basis for economical and stable system operation.

Sandip Gangil (2015) analyzed thermogravimetric spectra of binderless briquettes and its raw material, soybean crop residues and identified the changes occurring in the intrinsic biopolymeric components such as hemicellulose, cellulose and lignin due to briquetting stresses. The researcher found that both lignin and hemicellulose was found to participate beneficially in the formation of briquette. Activation energies were computed using the integral isoconversional

Friedman kinetics method. Deconvolution analysis showed that hemicellulose became less reactive after briquetting.

Nayara Vilela Avelar et. al (2016), evaluated experimentally the briquettes made from textile industry solid waste. The biosludge was mixed with cotton textile industry residues in different ratios. The results concluded that the mixing of residues for the production of briquettes can optimize their physical-chemical and mechanical characteristics depending on the mixing ratio used. Lei Guo et. al (2016) investigated the compression and relaxation properties of selected biomass for briquetting (barley, oat, canola and wheat straw) to determine the correlation with variables (pressure, particle size (hammer mill screen size) and moisture contents). The applied pressure ranged from 7.03 to 14.06 MPa. Three hammer mill screen sizes (19.05, 25.40 and 31.75 mm) were used to grind the biomass samples. The ground biomass materials were conditioned to moisture contents of 9%, 12% and 15% (w.b.). The results indicated that the compact density of biomass increased with increasing pressure and moisture content. The relaxation properties of selected materials were affected by the set variables. Biomass materials had a higher stress relaxation speed with higher applied pressure and lower moisture content. Xianfei Xia et. al (2016) carried out, a study on the optimization of a rice straw ring-die briquetting process combined analytic hierarchy process and grey correlation analysis. Experimental results indicated that moisture content and clearance between die and roller influenced the productivity, energy consumption and product density significantly while temperature and particle size have a relatively weak effect.

A. Amarasekara et. al (2017) studied the briquetting and carbonization processes of naturally grown algae biomass collected from regional lakes. The researchers concluded that as the compaction load increased, briquettes had ignition temperatures ranging from 492 to 520 °C. A load of 3 tons/cm² is the ideal condition for low manufacturing load and moderate-temperature-burning briquettes. The average ignition temperature on carbonized briquettes remained between 474 and 492° C. Reduction of the residual strengths of the algae briquettes by carbonizing was shown by residual strength tests on the specimens. Arshad Adam Salema (2017) carried out the pyrolysis of corn stalk biomass briquettes in a developed microwave (MW) reactor supplied with 2.45 GHz frequency using 3kW power generator. Based on its heating value and elemental composition, biochar is suitable for energy applications, whereas bio-oil produced from CS is neither good for energy application nor for chemical production. Reuben Shuma et. al (2017) studied the various production methods, procedures and processes that are deployed to process loose biomass into biomass briquettes. The researchers concluded that the optimum briquetting

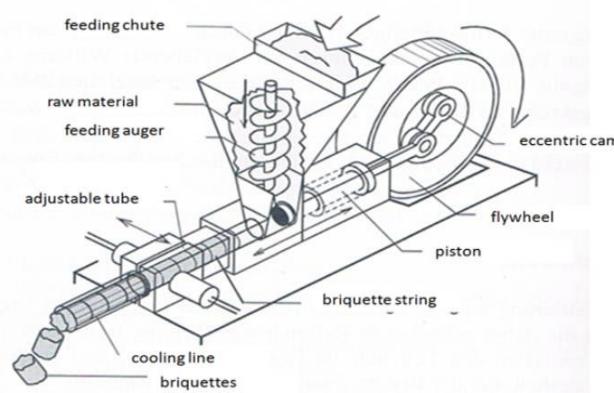
parameters are pressure of 19 MPa and loose biomass to binder ratio of 35:65

N.N. Chen et. al (2017) investigated the Infrared radiation drying behaviors of four typical biomass briquettes (populus tomentosa leaves, cotton stalk, spent coffee grounds and eucalyptus bark) based on a lab - scale setup. With increasing the radiation temperature from 100°C to 200°C, the average far-infrared drying rates of the leaves, spent coffee grounds and eucalyptus bark briquettes grew about 1.4-1.9 times. In addition to a warm-up stage, and two falling rate stages, the far-IR drying of the samples also presented a constant rate stage (below 180 °C). Among four biomass briquettes, the values of the average effective moisture diffusivity for the eucalyptus bark briquette in two falling rate stages were the highest ones, while that for the spent coffee grounds briquette was the smallest ones. With the radiation temperature growing from 100°C to 200°C, the average values for the surface temperatures of the briquettes increased by 42-52 °C.

### 3. METHODOLOGY

In generally the piston press and the screw extrusion are the most commonly used biomass briquetting technologies. In India, piston press is installed in number of commercial plants. But manufacturers are facing many problems with these presses because of effect of change in type of biomass on design parameters and life of machine.

#### 3.1 Piston Presses Technology



**Fig. 1. Piston Press Setup**

The piston presses are also known as ram and die technology. In this case the biomass is punched into a die by a reciprocating ram with a very high pressure thereby compressing the mass to obtain a briquette. The briquette produced is 60 mm in external diameter. This machine has a 700 kg/hr capacity and the power requirement is 25 kW. The ram moves approximately 270 times per minute in this process. There is less relative motion between the ram and



the biomass hence, the wear of the ram is considerably reduced. It is the most cost-effective technology currently offered by the Indian market. Some operational experience has now been gained using different types of biomass. The moisture content of the raw material should be less than 12% for the best results. The quality of the briquettes goes down with an increase in production for the same power. Carbonisation of the outer layer is not possible. Briquettes are somewhat brittle.

### 3.2 Screw Extrusion Technology

In the screw extrusion technology, the biomass is extruded continuously by a screw through a taper die which is heated

externally to reduce the friction. The output is continuous and the briquette is uniform in size. The outer surface of the briquette is partially carbonized facilitating easy ignition and combustion. This also protects the briquettes from ambient moisture. A concentric hole in the briquette helps in combustion because of sufficient circulation of air. The machine runs very smoothly without any shock load. The machine is light compared to the piston press because of the absence of reciprocating parts and flywheel. The machine parts and the oil used in the machine are free from dust or raw material contamination. The power requirement of the machine is high compared to that of piston press.

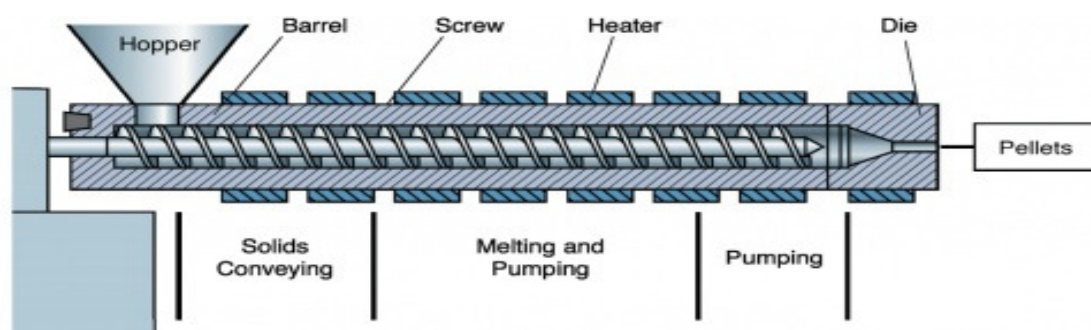


Fig. 2. Screw Extrusion Setup

### 3.3 Other Briquetting Technologies

Another type of briquetting machine is the hydraulic piston press. This is different from the mechanical piston press in that the energy to the piston is transmitted from an electric motor via a high pressure hydraulic oil system. This machine is compact and light. Because of the slower press cylinder compared to that of the mechanical machine, it results in lower outputs. The briquettes produced have a bulk density lower than  $1000 \text{ kg/m}^3$  due to the fact that pressure is limited to 40-135 kg/h. This machine can tolerate higher moisture content than the usually accepted 15% moisture content for mechanical piston presses.

Pelletizing is closely related to briquetting except that it uses smaller dies (approximately 30 mm) so that the smaller products are called pellets. The pelletizer has a number of dies arranged a holes bored on a thick steel disc or ring and the material is forced into the dies by means of two or three rollers. The two main types of pellet presses are: flat and ring types. The flat die type features a circular perforated disk on which two or more rollers rotate. The ring die press features a rotating perforated ring on which rollers press onto the inner perimeter. Large capacity pelletizers are available in the range of 200 kg/h to 8 ton/h. Thus, pellet press capacity is not restricted by the density of the raw material as in the case of piston or screw presses. Power consumption falls within the range of 15-40 kWh/ton.

## 4. CONCLUSION

In this presented paper, a brief review on the biomass briquetting process is carried out. The various aspects related to briquetting process like effects of temperature, pressure, moisture, availability and cost of biomass were studied. In developing countries like India which are having agricultural based economy, emphasis should be given for the research and development of technology for utilizing its biomass potential. It will be helpful for minimizing the environmental impacts caused by use of coal for power generation. There is a lack of prominent research and investigations on locally available type of biomass in India and more development based on feasibility and economy should be carried out in designing parameters of briquetting machines.

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# Development of Java Code Program for Design of Knuckle Joint

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**Abstract** :A knuckle joint is used to connect two circular rods, which are under action of tensile loads. A knuckle joint may be easily disconnected for adjustments or repairs. The aim of the present paper is to study and calculate various loads acting on knuckle joint. In this paper with the help of java programming the design calculations of knuckle joint are calculated. Knuckle joint is subjected to tensile, crushing, and shear failures. Therefore it is necessary to calculate above values. These values are calculated by using java code programme. Design of knuckle joint refers to calculations of various dimensions considering the failures under shear, crushing, tension. This paper also represents development of java code to simplify the design methodology. It was observed that the calculation time is significantly reduced and manual errors in calculations are avoided using the JAVA code development.

**Keywords**: Tensile Failure, Shear Failure, Crushing Failure, Java program.

## 1. INTRODUCTION

A knuckle joint is used to connect two circular rods, which are under action of tensile loads as shown in Fig 1. A knuckle joint may be easily disconnected for adjustments or repairs. In knuckle joint, one end of rod is made into shape of an eye in each of the fork leg. The knuckle pin passes through both of the eye hole and the fork holes and may be secured by means of collar and taper pin as split pin. It allows angular movement of the rod in plane about the axis of pin. At one end of the rod the single eye is formed and double eye is formed at the other end of the rod. Both, single and double eye are connected by a pin inserted through

eye. The pin has a head at one end and at other end there is a taper pin or split pin. For gripping purpose the ends of the rod are of octagonal forms. Now, when the two eyes are pulled apart, the pin holds them together. The solid rod portion of the joint in this case is much stronger than the portion through which the pin passes. The knuckle joint assembly consists of following major components:

- Single eye.
- Double eye or fork
- Knuckle pin.

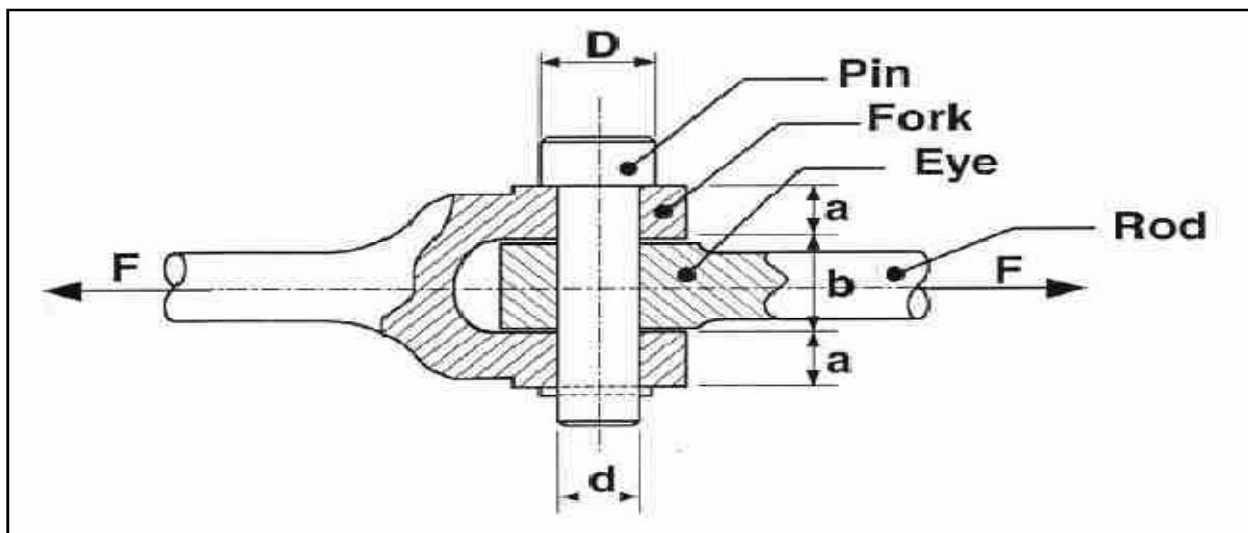


Fig. 1. Knuckle Joint [Bhandari, V.B. (2010). Introduction to machine design 3rd edition, 94-99.]



## 2. LITERATURE REVIEW

In order to get the details of JAVA programming applied to Design of machine elements a literature review is carried out:

**Dinesh Shinde and Kanak Kalita 2015** have carried out study of knuckle joint and performed a FE analysis on knuckle joint pin used in tractor trailer. They also studied stress in knuckle pin during acceleration and deceleration of tractor trailer. Tangential force is acting on knuckle joint, they carried out this force calculation when trailer is empty and when trailer is full in both accelerated and decelerated conditions. Modelling and simulation is also done in CATIA and ANSYS.

**Smit S. Bhosle et.al 2015** have carried out study on Two stage spur gear box and developed a java code to calculate all theoretical design values and selection of material required for spur gear. In this work, they calculated the forces which are acting on spur gear by user inputs of input speed, output speed, power required. They simplified the process of manual calculation using java coding.

**Sangamesh B. Herakal et.al 2016** have carried out structural static analysis of knuckle joint by using CATIA for modelling and HYPERMESH for FE analysis. They

achieved analytical stress distribution which occurs in knuckle joint.

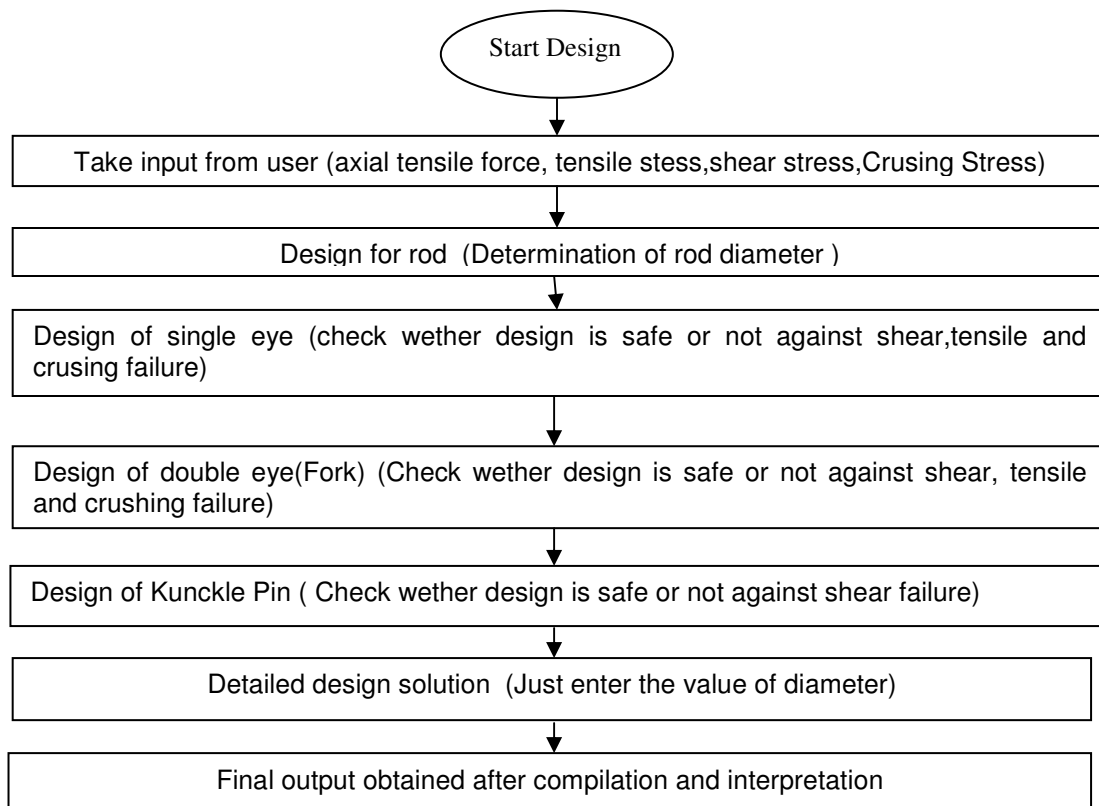
**Yaswanth Peddireddy and S. Sundar 2015** have studied knuckle joint and they developed an integrated application of design process and generating model of a knuckle joint using a visual basic and solid works. This methodology concentrates on the making a Knowledge Base Engineering. In this work, the database of a material properties and standard design information of a knuckle joint is prepared in forms by using Visual Basic Environment. Where the user can select design process by selecting a command controls that are to be created in the IDE, from that the main form to be appear thereby user can select the given options to design and model of knuckle joint.

It was observed that programming significantly simplifies the design process. However, the reported literature indicated a least work is done for design of knuckle joint using JAVA Programming.

## 3. OBJECTIVE

As per the research gap observed, the objectives of current work were decided as to develop a JAVA code for Design of Knuckle Joint in order to simplify the design process.

## 4. ALGORITHM OF JAVA PROGRAMME IS DEVELOPED FOR DESIGN OF KNUCKLE JOINT.



## 5. RESULTS

- i) The GUI developed is user friendly.
- ii) This code was being tested for various loads and found to be sustainable for Design of Knuckle joint.
- iii) The testing of code has yielded the following results :
- iv) Input parameters in GUI is shown in Fig 2.

```
<terminated> kj [Java Application] C:\Program Files\Java\jre1.8.0_144\bin\javaw.exe (09-Oct-20
DESIGN OF KNUCKLE JOINT
Press 1 for design of rod
Press 2 for design of single eye end
Press 3 for design of double eye end
Press 4 for design of knuckle pin
Press 5 To summerise overall dimensions
1
We are designing rod considering its tensile failure
Enter axial tensile force applied to rod
30
Enter tensile stress for rod
56
Diameter of rod=0.8259011626685485mm
Rounded Diameter=1.0mm
We are designing single eye
Checking against tensile failure
Enter tensile force applied to rod
30
Enter diameter of rod
0.82
Tensile stress in rod=35.693039857227845N/mm^2
Enter permissile tensile stress
56
Design is safe against tensile failure
Shear stress in rod=35.693039857227845N/mm^2
Design is safe against shear failure
Crushing stress in rod=35.693039857227845N/mm^2
Enter permissible crushing stress
70
Design is safe against crushing failure
We are designing double eye
Checking against tensile failure
```

Fig. 2. Input Parameters in GUI

- v. The **Output** given by JAVA programming is shown in Fig 3.

```
<terminated> kj [Java Application] C:\Program Files\Java\jre1.8.0_144\bin\javaw
Enter tensile force applied to rod
30
Enter diameter of rod
0.8259
Tensile stress in rod=29.320749219617262N/mm^2
Enter permissible tensile stress
56
Design is safe against tensile failure
Shear stress in rod=29.320749219617262N/mm^2
Design is safe against shear failure
Crushing stress in rod=58.641498439234525N/mm^2
Enter permissible crushing stress
70
Design is safe against crushing failure
We will design knuckle pin
Enter tensile force applied on pin
30
Enter dia of rod
0.8259
Shear stress in rod=28.00007883458596N/mm^2
Enter permissible shear stress
35
Design is safe against shear failure
We will summarise all dimensions
Just enter diameter of rod
0.8259
Diameter of pin=0.8259mm
Diameter of single eye=1.6518mm
Diameter of knuckle pin head & collar=1.23885mm
Thickness of single eye=1.032375mm
Diameter of double eye=0.619425mm
Diameter of collar pin=0.41295mm
```

Fig. 3. Output given by JAVA Compiler

## 6. CONCLUSION

Following conclusions are derived from present work:

- This design provides a safe design for Knuckle joint using JAVA Programme.
- Manual calculations are simplified by using java code.

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# A Literature Review on Low Cost Sugar Cane Cutting Machine

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**Abstract:** The aim of this paper is a small work towards analyzing sugar cane harvester machine aspects for economical harvesting which will help to minimize the working fatigue and to reduce labor cost. In today's competitive world there is a need for faster rate of production of agricultural products. Agriculture is the backbone of India. In India almost all farmers facing problems of labor shortage. Day by day labor wages are increasing and in the same way demand of agriculture products. In India agriculture has facing serious challenges like scarcity of agricultural labor, not only in peak working seasons but also in normal time. This is mainly for increased nonfarm job opportunities having higher wage, migration of labor force to cities and low status of agricultural labors in the society. Sugarcane was harvested at 12 month's after planting with an average stalk length of 1.8 m, and average-stalk diameter of 0.0254m; each clump consisted of 8 to 12 stalks, The distance of each sugar cane row was 1.20 m (T. Moontree, S. Rittidech, 2012). Thus it is mostly needed to be focused on it to improve production of sugarcane. Harvesting is a process of cutting and gathering of mature crop from the field. Harvester is a machine is used for harvesting or a cutting process. As per farmer requirement, these field crops are cut and collected in bunches.

**Keywords:** Sugar cane, Stalk, Harvesting

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## 1. INTRODUCTION

Agriculture is one of the most significant sectors of the Indian Economy. Agriculture is the only means of living for almost two thirds of the workers in India. The agriculture sector of India has occupied 43% of India's geographical area, and is contributing 16.1% of India's GDP (Gross Domestic Product). Agriculture still contributes significantly to India's GDP despite decline of its share in India's GDP. There are number of crops grown by farmers. These include different food crops, commercial crops, oil seeds etc. Sugarcane is one of the important commercial crops grown in India. Sugarcane is the world's largest crop 2010 Food Agricultural Organization (FAO) estimates it was cultivated on about 23.8 million hectares in more than 90 countries, with a worldwide harvest of 1.69 billions tons. Brazil was the largest producer of sugarcane in the world and India in second position. India is a home of thin class of canes. There are historical and botanical evidences to prove it. India is the second largest producer of sugarcane in the world and Brazil in first position. India is produce 351 million tonnes of Sugarcane and 28 million tonnes of sugar in 2014-15. "Indian Institute Of Sugarcane Research" (IISR).

Approximately 80% of the world's sugar is produced from sugarcane in tropical and subtropical climates, with the remaining 20% derived from sugar beet, which is grown mostly in the temperate zones of the northern hemisphere. 70 countries produce sugar from sugarcane, 40 from sugar beet and 10 from both. In India's sugar production increased to 11.5% during the 2014-15, season on bumper cane

production, the world sugar production amounted to approximately 175.1 million metric tons. Asia was the largest sugar-producing region in the world, yielding approximately 66.12 million metric tons of sugar. India, China and Thailand where the region's top sugar producer.

In India agriculture is facing serious challenges like scarcity of agricultural labour, not only in peak working seasons but also in normal time. This is mainly for increased nonfarm job opportunities having higher wage, migration of labour force to cities and low status of agricultural labours in the society. (Jain et al. 2013)

## 2. LITERATURE REVIEW OF SUGAR CANE CUTTING PROCESSES

Various harvesting practices are used in sugarcane production, each requiring different harvesting technologies to ensure effective and efficient field operations. The cited findings are presented in this chapter under following heads:

- 2.1 Harvesting Practice
  - 2.1.1 Green cane harvesting
  - 2.1.2 Burnt cane harvesting
- 2.2 Harvesting Mode
  - 2.2.1 Whole stalk harvesting
  - 2.2.2 Chopper harvesting
- 2.3 Base-Cutting Mechanism
- 2.4 Energy for Cutting Force
- 2.5 Physical Properties of Sugarcane Crop

## 2.1 HARVESTING PRACTICE

### 2.1.1 Green Cane Harvesting

Eiland and Clayton (1983) evaluated the fuel consumption and machine performance of four mechanical harvesters in Florida. The evaluated harvesters were: 1. Single-row, narrow throat, and rubber tires; 2. Single-row, wide-throat, and tracks; 3. Single-row, narrow throat, and tracks; 4. Single-row, wide-throat, and rubber tires. They found that the fuel consumption with green cane harvesting was increased by 12% and the harvesting efficiency was decreased by 17% compared to burnt cane harvesting.

Nunez and Spaans (2008) reported that weed control and irrigation costs after green cane harvesting were reduced by



**Fig.1. Green cane harvesting system**

### 2.1.2 Burnt cane harvesting

Deepchand (1986) determined the burning process, fire is set in a confined predetermined field, which burns off leafy extraneous materials, including stalk tops and dry leaves. Sugarcane composition showed that the amount of leafy materials constitute about 37% of whole cane plant dry matter and about 42% of cane plant dry matter above the ground. Pre-harvest burning burns off about 80% of cane leafy materials leading to 30% to 40% improvement in harvester productivity.

Lionnet (1986) conducted an experiment to burning of cane ensures a cleaner cane entering the mill, making the milling process more efficient. The reduced leafy materials lead to reduced waste in sugar production including adherent clay, sand, and mud contaminating the sugar and cane burning causes wax removal; cane splits, and juice leakage, which facilitates the infection of canes with cane deteriorating micro-organisms.

Cancado et al. (2006) reported that, pre-harvest burning has become one of the most sensitive environmental issues faced by local communities and public pressure against cane burning is also increasing worldwide because of

35% and 10%, respectively and soil fertility could be enhanced by increasing soil C and N contents by 0.47 and 0.07 mg/ha/year, respectively, under green cane harvesting.

Wiedenfeld (2009) found that the soil organic matter content after three years was increased by green harvesting compared to burning prior to harvest. Harvesting green compared to burning caused a 20% reduction in yield in the 2nd ratoon and a slight reduction in crop growth but an 8% increase in sucrose content in the 3rd ratoon crop. While the effects due to green harvesting on soil properties and crop growth were relatively minor, the residue remaining on the soil presents considerable challenges in cultivation, weed control and irrigation. Differences in sugarcane yields due to harvesting green vs pre-harvest burning have been inconsistent.



**Fig.2. Burn cane harvesting system**

growing environmental and health concerns. It has been reported that cane burning.

## 2.2 HARVESTING MODE

### 2.2.1 Whole stalk harvesting

Kiatiwat et al. (1992) developed a self-propelled walking type sugarcane harvester-windrower in Thailand. The machine is a one row single-axle walking-behind-type. It works on the principle of impact cutting by knife blades. As the machine moves forward along the row, the cluster of cane stalks is guided from the divider by a two sets of lugged chains and a spring loaded guide frame. At the narrowest point of guided path, the canes are cut by blades of the base cutter, revolving at peripheral speed approximately 42 m/s. A pair of solid rubber-gage tractor wheels mounted in the front part of the machine prevents the base cutter blade from striking the ground and control the height of cut. The machine type is 4GZ-9 whole stalk harvester, mounted on 11-14.7 kW hand tractor. Its productivity is 0.1-0.15 ha/h, and it is adapted to row spacing  $\geq 1.0$  m. shifting a lock-pin along the shaft to make adjustment for various spacing along the adjacent rows.

Salassi et al. (1996) compared that the performance ratings for a single-row whole-stalk harvester and a double-row whole-stalk harvester, a single-row chopper harvester, a loader (combine harvester), and a transloader (whole-stalk harvester). For a whole-stalk harvester, the per hour cost of a single-row machine was 35% less than that of the double row machine. However, per acre cost was 69% more expensive because the field capacity (acres/h) of a single row harvester was 61% less than a double-row harvester. Per hour cost for a single row chopper harvester was even higher than a double-row whole-stalk harvester because of more work load and energy consumption.

Gupta et al. (1996) design and developed a new low-cost, self-propelled, single-axle walking-type sugarcane harvester powered by 6-kW (8-hp) gasoline engine. It was primarily designed for farmers of developing countries who cannot afford to purchase expensive sugarcane harvesters used in developed countries. This machine reduced labour.

Moontree et al. (2012) developed sugarcane harvester using small engine in order to focus on its appropriateness in sugarcane farming for farmers who are encountering problems of labor shortage and sugar factories lack sugar cane for producing sugar. It is operated by 180 hp (134.28 kW) at 2500 rpm. Sugarcane was harvested at 12 months after planting with an average-stalk length of 1.8 m, and average-stalk diameter of 0.0254 m, each clump consisted of 8 to 12 stalks, the distance of each sugarcane row was 1.20 m. The sugarcane harvester using small engine can perform at an average speed of 1109.73 m²/h with fuel consumption of 20.03 l/h and at a mobile speed of 0.25 km/h. The percentage of sugarcane-cut stalks is 100%.

Bastian and Shridar (2014) carried out study on mechanical properties of the plant material were done prior to the design of sugarcane harvesting system and also significantly influence the performance of the different unit operations in combine harvester. The mechanical properties of sugarcane stalk viz., bending resistance, cutting resistance, penetration resistance and crushing resistance were studied in the laboratory. It is found that the Young's modulus of the sugarcane stalks as 86MPa, The specific cutting resistance varies between 1764.56 and 957.48kNm⁻², penetration resistance ranged from 29.74kNm⁻² to 56.33kNm⁻² and the crushing force varied from 0.75kN to 1.53kN.

Ranveer Tambuskar (2015) design and developed, Sugarcane harvesting by a machine has a more capacity to cut the sugarcane faster compared to the manual one. Hence, need of using sugarcane harvester in India is necessary for faster rate of production of sugarcane products as well as harvesters take less time to cut the cane and cuts cane in smaller parts so that it becomes easy to transport with larger amount of quantity in one trolley. These Cutting machine has conveying and collecting

methodology of a sugarcane harvester as an attachment to the tractor which takes the power from tractor only through its for sugarcane harvesting to reduce farmer's effort and to increase production of agricultural products of sugarcane harvester at the lower cost which can be affordable to Indian farmers or a group of farmers. The cost of an attachments goes up to Rs.35000/.

### 2.2.2 Chopper harvesting

The chopper harvester includes a mechanism to chop stalks into uniform sized pieces. This concept was proposed in 1955 by Ken Gaunt, an Australian engineer to simplify cane handling operation. Gaunt led a team to fabricate the first sugarcane chopper harvester that included a chopping unit, which resulted in a basic technology for the chopper harvesters.

Yadav et al. (2002) carried out the performance evaluation of sugarcane chopper harvester, most of the large-scale imported harvesters and the current price is very expensive. In addition, the large-scale imported harvesters are designed for large-scale farming areas, which require 1.50 m of the distance of each sugarcane row. Some of the small-scale Thai farming areas employed the sugarcane row distance of 1.2 m. Therefore, it is not possible for the large-scale harvester to drive through the row. Thus, solving these problems by designed and developed a sugarcane harvester using small engine. This would be benefit for small-scale farmers in our country.

Singh and Solomon (2003) reported that the chopping process accelerates sugar deterioration because of the easy access of bacteria through abrasion, failure points, and cut surfaces in chopped billets. The harvested billets need to be milled as fast as possible. Seven days after harvesting, cane billets had 18.93% of weight loss whereas whole stalk canes had 13.6% of weight loss.

### 2.3 Base-Cutting Mechanism

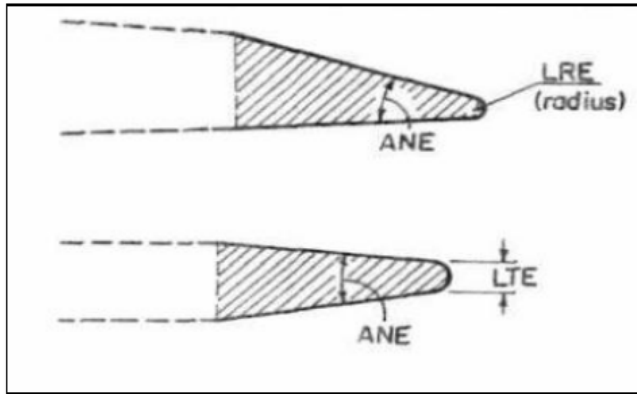
Persson (1987) reported that the knife consists of an edge and the blade where the edge is part of the blade. The edge starts where the blade begins to taper and is seen as the shaded section in Fig.3 Three other important features of the knife are also illustrated in Fig.4: These are:

- 1) Angle of edge (ANE) that is defined as the angle between the two cutting face's called fineness,
- 2) Longitudinal radius of edge (LRE), which defines the knife sharpness, and
- 3) Longitudinal thickness of edge (LTE) or dullness of the knife

Gupta and Oduori (1992) reported that the operating characteristics of knifetype sugarcane base cutter, investigated the relationship between cutting force and

system parameters including blade oblique angle, cutting disc tilt angle, and blade cutting velocity. It was found that:

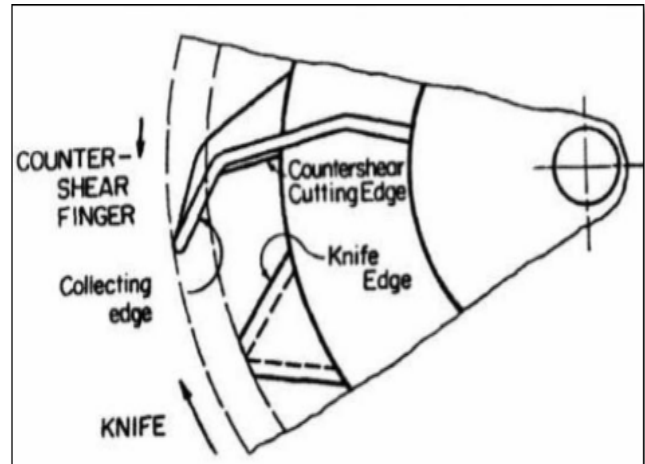
1. The desired blade cutting velocity ranged from 13.8 to 18.4 m/s (the power consumption will increase extensively when the velocity is more than 19.4 m/s).



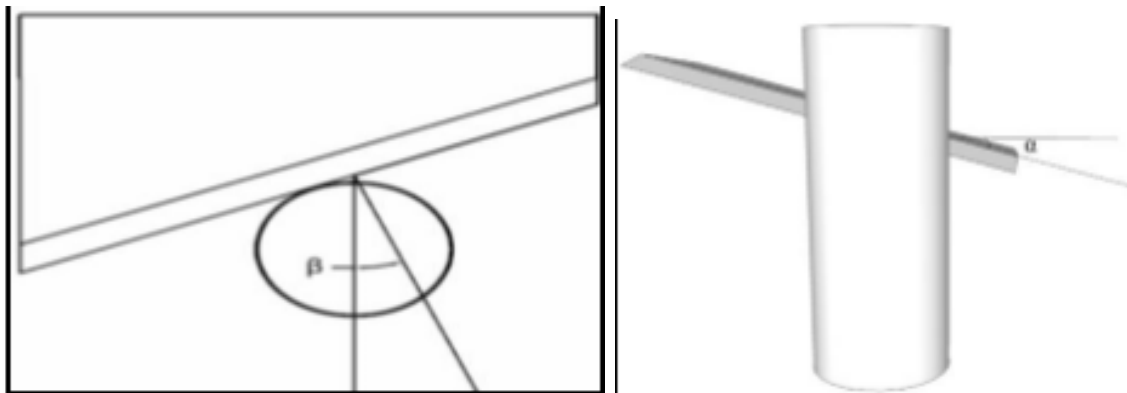
**Fig. 3. Dimensions of a knife to illustrate the edge angle (ANE), edge radius or knife sharpness (LRE) and the edge thickness or dullness (LTE)**

2. The desirable blade oblique angle was between  $20^\circ$  and  $50^\circ$ .

3. The recommended operating tilt angle was from  $25^\circ$  to  $50^\circ$ .



**Fig. 4. Top view of the counter shear finger and knife**



**Fig. 5. The blade oblique angle( $\beta$ ) and tilt angle ( $\alpha$ )**

Mello and Harris (2003) conducted geometric parameter studies of serrated blades, which included two important factors: the length of serration pitch (the distance from a point on one projection to the same point on an adjacent projection) and geometric shape (forward or backward curved). They carried out two-factorial experiment to test two kinds (forward and backward curved) of serrated blades with different pitches (3 and 7 mm) examining cutting energy spent for cane cutting. It was concluded that the forward blade with 3 mm pitch has the best result among the configurations evaluated.

Jun et al. (2012) analyze the experiment was conducted with the traditional manual harvesting and mechanical

harvesting of sugarcane, to compare the effects of different harvesting method on the sugarcane stubble quality and the growth of ratoon. The experimental results are as follows.

1. The stubble height and breaking stubble rate of mechanical harvesting was significantly higher than manual harvesting, the stubble height of lodging species and difficult defoliation species increased in mechanical harvesting condition. Varieties with higher levels of fiber had lower rate of broken stubble.
2. The effects of mechanical harvesting on germination of next year ratoon were quite different due to different varieties, indicating that the better perennial species have less impact than the poor perennial species.

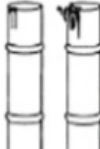
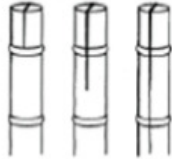
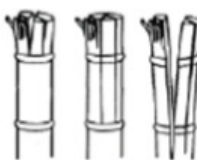


3. Compared with manual harvesting, mechanical harvesting had slightly higher plant height and single-stem weight and less effective stems number, the degree of damage caused.

**TABLE 1: Classification of the damages caused to stalks after mechanized harvest Lower limit**

Disc	Normal	Tilted	Fast exchange
External diameter, mm	563	563	563
Thickness, mm	12.7	12.7	12.7
Weight, kg	26.5	26.5	25.8
Number of blade	5	5	5
Blade angle, (°)	-	15	4.36
Material, (SAE 1020)	Chromium steel	Chromium steel	Chromium steel

**TABLE 2: Mechanized harvest, using statistical quality control tools**

Classification	Lower limit	Upper limit	Weight
Undamaged (SD)			-1.00
Partially damaged (P.D.)			-0.33
Severely damaged (E.D.)			1.00

Source : Mello and Harris (2003)

## 2.4 Energy for Cutting Force

Liu et al. (2007) compared the stalk damage rates caused by one-blade and two-blade cutting. It was concluded that the two-blade cutting process has lower stubble damage rate than one-blade cutting. The reason is that the maximum cutting force required during one-blade cutting is bigger than the maximum cutting force required during two-blade cutting, thus one-blade cutting has a greater probability of stalk cutting failure (split or crack). To improve the stalk

cutting quality, the study suggested increasing the ratio of cutting disc rotational speed to machine forward speed. The cane stalk cutting process by a rotating cutting disc. Equation 1 is used to determine the ratio (R) of cane stalk diameter (D) to the distance ( $v_m a / \omega$ ) of two adjacent blade tips in the direction machine is moving. When  $R < 1$ , the cane stalk is cut off only by one blade (called one-blade cutting). When  $R > 1$ , the cane stalk is cut off by two or more adjacent blades. Since cane stalk diameter (D) and the angle

( $\alpha$ ) are constant, the ratio ( $r$ ) between cutting disc rotational speed ( $\omega$ ) and machine forward speed ( $v$ ) determines whether it will be one-blade cutting or multiple blade cutting.

Stalk cutting quality

$$R = D / (v\alpha/\omega) = Dr / \alpha$$

Where,

$R$  = The ratio of cane stalk diameter to the distance of two adjacent blade tips in the machine moving direction

$r$  = the ratio of cutting disc rotating speed to machine forward speed

Taghinezhad et al. (2013) studied using a linear blade cutting and UTM device to determine of the effect of sample moisture content with respect to the cutting element and quantify the possible cutting energy reduction. Also the effect of the dimensional parameters on mechanical cutting properties were studied on small, medium and large size for cutting force, energy, ultimate stress, and specific energy of sugarcane stalks. The device was used along with a universal test machine that quantified shearing stress and energy characteristics for applying force on sugarcane stalks through a blade device. Mean specific cutting energies of cane stalks at low, medium and high levels of moisture content were 34.071, 28.339 and 16.297 kN/m and for ultimate stress were 7.086, 2.586 and 1.656 MPa, respectively. Also other parameters of mechanical cutting such as energy and peak force were presented and the results showed a significant difference between levels of moisture content and dimensional parameters in mechanical cutting properties. The high moisture content level compared to low moisture content level produced a significant reduction in the ultimate stress and the specific energy by about onesecond.

Sureshkumar and Jesudas (2015) where conducted laboratory and field measurements preliminary data for cutting and lifting behavior of sugar cane stalk, used for design of the sugar cane harvester. Laboratory studies were conducted to measure the mechanical properties of sugarcane stalk. An apparatus was developed to measure the lifting moment of sugarcane stalk from the lodged position to vertical under field conditions. To measure the cutting energy a pendulum type impact cutting device was used, Flexure test were conducted for measuring the modulus of elasticity. The maximum lifting moment varied from 30.62 Nm to 129.11 Nm and the lifting moment was dependent upon the field conditions and degree of entanglement. The specific cutting energy increased linearly when the oblique angle was increased from 0 to 350 and the specific cutting energy was lowest at a tilt angle of 200 when the oblique angle was 300. The flexure test on sugarcane stalk as a simple supported beam gave Young's modulus values of 1165.27 to 1667.11 M Pa. The

same when loading was done as cantilever beam was 2266.17 to 2905.61 M Pa.

## 2.5 Physical Properties of Sugarcane Crop

Anon (2010) carried out the ripening and maturation phase in a twelvemonth crop lasts for about three months starting from 270-360 days. Sugar synthesis and rapid accumulation of sugar takes place during this phase and vegetative growth is reduced. As ripening advances, simple sugars (monosaccharide viz., fructose and glucose) are converted into cane sugar (sucrose, a disaccharide). Cane ripening proceeds from bottom to the top and hence bottom portion contains more sugars than the top portions. Ample sunshine, clear skies, cool nights and warm days (i.e., more diurnal variation in temperature) and dry weather are highly conducive for ripening.

Bastian, and Shridar, (2014) Conducted the physical properties of sugarcane pertaining to de-topping, de-trashing and conveyance are studied for the designing of a whole stalk sugarcane harvester. The various physical parameters for the major varieties of sugarcane are measured in the farmers' field. The farmers' grow CO 86032 sugarcane at a row spacing of 75 to 100cm, and the spacing is increased to 150 and 200cm wherever harvesting is done by self propelled combine harvesters. The average number of cane per meter varied from 27 to 30. The length of the millable cane varies between 1200 mm and 2700 mm. The maximum and minimum diameters are 40 and 20 mm respectively. The trash content at the time of harvesting was 38.56 percent where the regular de-trashing processes were completely skipped by farmers.

## 3. CONCLUSION

The main purpose of this review paper is to understand the different aspects of old as well as new harvesters and also harvesting method scenario to reduce the efforts which were put in by farmers in terms of time, money, labours, physical efforts for improving productivity and optimum performance. Above discussed terms will provides an ideas for manufacturing a new type of machine they over come the above parameters and also provide more profit, stability in terms of economical considerations and machine to be design will helps to both small or big farms. Definitely farmers can overcome the labour scarcity problem.

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# Finite Element Analysis of Two Wheeler Spokes Pattern for Optimization: A Case Study

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**Abstract:** Automobile wheel material and design have vital significance in the smooth operation of a vehicle subjected to varying road conditions. The purpose of the bike wheel rim provider's a firm base on which to fit the tire. Its dimensions, the shape should be suitable to adequately accommodate the particular tire required for the vehicle. This paper explores the designing of new and lighter alloy wheel similar to the existing design through the reverse engineering process. This project investigates new design for two wheeler bike rim. The CAD modeling of the rim is done in CREO 2.0 and analysis of rim is done in ANSYS14.0 using method of finite element analysis. A typical alloy wheel configuration of Hero deluxe commercial vehicle is chosen for study. The metal configurations are made from either cast or cast plus forged aluminum alloys in the present and newer generations of ground vehicles.

**Keywords:** Optimization, Wheel Rim, ANSYS, Creo, Structural Analysis

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## 1. INTRODUCTION

Archaeologies and historians of today see the introduction of the wheel as the real genesis of any old civilization. The wheel is perhaps the most significant discovery of old times. The wheel has developed from nothing more than an oversized bearing to a fully integral part of any modern transportation vehicle. The modern vehicle is also seen today a fashion item to complement people's individual requirements. Motor vehicles are produced according to very strict rules to ensure the safety of the passengers. Every component is therefore designed according to the criticality of the component. Wheels are classified as a safety critical component and international codes and criteria are used or design a wheel. Materials to produce these wheels have become as sophisticated as a design and materials can range from steel to nonferrous alloys like magnesium and aluminum.

The size of the wheel rim governs how much space there is between the rim and the brake rotor. By moving up to a higher diameter wheel rim there will be more scope for air flow around the brakes and therefore better cooling. The weight of the wheel rim is an obvious issue. The mass is not only important in terms of the overall weight of the wheel, the rotational inertia of the wheel goes up with more weight as well, causing, even more, work on the brakes. The handling of a vehicle is always improved with light weight. As in case of ride, the lighter the unsprung weights are more easily controlled in the motion of the tire wheel and the better the adhesion to the road surface.

## 2. LITERATURE SURVEY

Panda et al., 2016 This paper starts by modeling of the alloy wheel in a two-wheeler racing bike using the Pro/Engineer Software for five different materials viz. LM 25, LM25TB7, LM 25TE, LM25TF and AM60A and conducting the tests: Static and Fatigue analysis using the CATIA software by reducing the number of spokes from 6 to 5 and then 5 to 4 for the existing model. The current design is 60% lighter than the original design/

Manjunath Batli et al., 2016 in this project work the entire wheel design of two wheelers was chosen and analyzed by applying different load and redesign the wheel again to minimize the deformation and material will be changed as per the analysis results. It is concluded that the existing design is not suitable for Magnesium alloy, structural steel. So change the design and the materials and analyze the stresses and finally conclude that Aluminium 7075 can be replaced by Magnesium alloy.

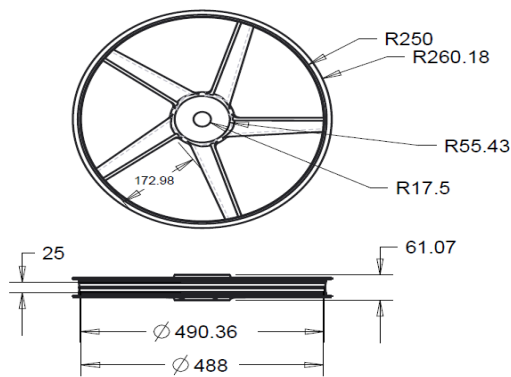
Kale et al., 2015 This paper deals with the static & fatigue analysis of the wheel. The present work attempts to analyze the safe load of the alloy wheel, which will indicate the safe drive is possible. A typical alloy wheel configuration of Suzuki GS150R commercial vehicle is chosen for study. Finite element analysis has been carried out to determine the safe stresses and pay loads.

## 3. METHODOLOGY

FEM is based on the concept of discretization. Any object is continuous and has an infinite number of atoms and molecules bonded together and therefore have infinite degrees of freedom and therefore would take infinite time

to solve in this approach. The basis of discretization is converting an infinite number of atoms and molecules to a finite number of elements and nodes. The concept of FEM involves three stages pre-processing, solution and post-processing.

We have first taken all the dimension of the existing Aluminum alloy wheel by the reverse engineering process According to the dimension profile of the component is drawn on the screen of the computer using Creo2.0. It is sketch based, feature based parametric 3D modeling software developed by PTC with parametric nature. Existing Z shape spokes replaced by I shape spokes and existing wheel rim material: Al 356.0-T61 has taken for the calculations of Equivalent Stress and Natural frequencies.



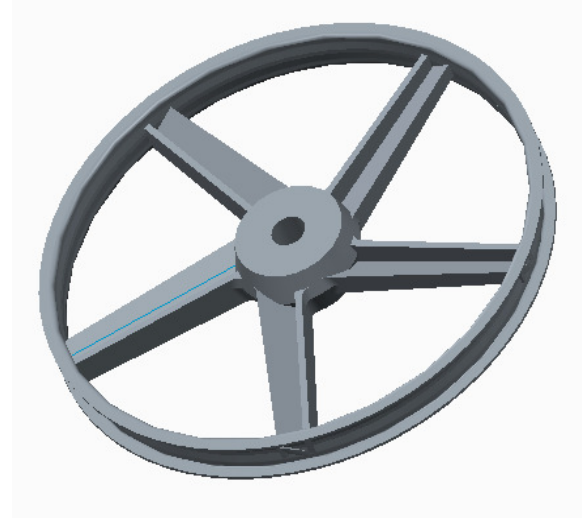
**Fig. 1. Dimensions of rim**

This model is then saved into IGES file format and is then imported into CFX 14. In ANSYS CFX geometry modeler, the model imported from Creo Parametric will have the same dimensions as that in Creo Parametric. Z section spokes and I section spokes modeled in Creo Parametric and analyzed in Ansys 14.0 software with aluminum alloy material.

3D isometric view of Z section and I section spokes wheel rims are shown below which is modeled in Creo parametric 2.0.



**Fig. 2. 3D Geometric model of I section**



**Fig. 3. 3D Geometric model of Z section**

The meshing work was accomplished on commercially available ANSYS meshing software. The geometry created was imported in ANSYS meshing. The meshed domain consisted mostly of uniformly sized cells. Fine meshing was completed with tetrahedral elements near the hub. The mesh size increased towards the center. Two different pressure forces were applied on the outer surface of the wheel rim and the hub of wheel rim remain fixed.

#### Calculation of loads

First case = mass of Bike (107 kg) + average mass of one person (65 kg)

Second case = mass of Bike (107 kg) + average mass of two persons (65 kg*2=130 kg, Other Loads = 20 kg  
Total mass in first case is 107+65+20 = 192 kg  
Total mass in second case is 107+65+65+20 = 257 kg, The total weight in first case Newton= 192*9.81=1883.52 N

The total weight in second case = 257*9.81 =2521.17N, 30% of Loads reduced by Tires and Suspension system

Therefore net weight W1 = 0.7*1883.52 = 1318.46 N, Net weight W2 = 0.7*2521.17 = 1764.81 N

Z and I section wheel rim area = 63959 mm²

Net weight on each wheel rim in case 1 = 1315.46/2= 659.23 N

Net weight on each wheel rim in case 2 = 1764.81/2= 882.40 N

Pressure force in load 1 case = (Force/Area) = 659.23/63959 = 0.0103 N/mm²

Pressure force in load 2 case = (Force/Area) = 882.40/63959 = 0.0137 N/mm²

The I-shaped model is tested for material optimization using Al 356.0-T6 and Mg AM60A those properties are shown in table 1.

**TABLE 1: Mechanical Properties of Al alloy**

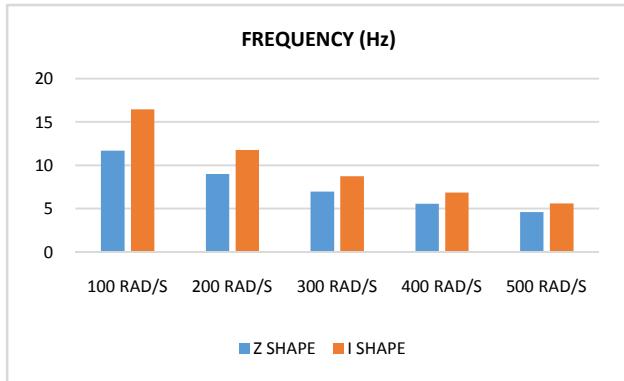
Mechanical Properties	Al (356.0-T61)
Yield strength	$\geq 179$ N/mm ²
Elastic modulus	72400 N/mm ²
Poisson's ratio	0.33
Mass density	2.67 gm/CC

#### 4. RESULTS AND DISCUSSION

Modal analysis of wheel rim is performed for angular velocities of 100rad/s, 200 rad/s, 300rad/s ,400 rad/s and 500 rad/s. The natural frequency is calculated from software and corresponding mode shapes are plotted for I and Z shaped profile.

**TABLE 2: Natural frequency for I & Z shape models with Al 356.0-T61**

Angular Velocities (rad/sec)	Natural frequencies (HZ) for Z section spokes wheel rim	Natural frequencies (HZ) for I section spokes wheel rim
100 rad/sec	11.69	16.45
200 rad/sec	8.99	11.74
300 rad/sec	6.94	8.72
400 rad/sec	5.55	6.83
500 rad/sec	4.58	5.59

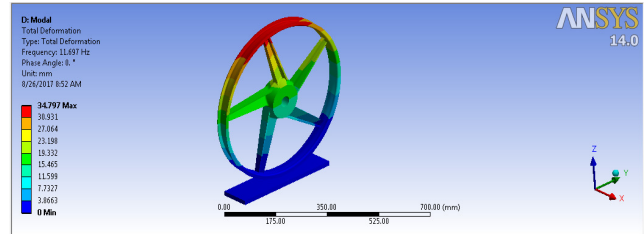


**Fig. 4. Natural frequency comparison bar graph**

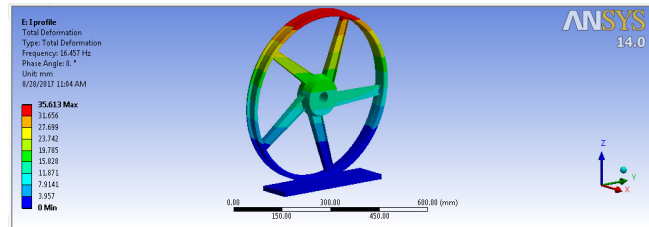
The natural frequency found to be decreasing with increase in wheel revolutions for both I and Z section wheel rim. A bar graph is shown in fig 4 which indicates that I profile has a higher frequency for all the revolutions compared to Z profile wheel rim.

The calculated natural frequencies are shown in Table 2. The first mode shape frequencies for five different angular

velocities with Aluminum alloy (356.0-T61) for both Z and I spokes wheel rim were shown in table 2. First mode shape for 100 rad/s is showing in fig 5 and 6.



**Fig. 5. 1st mode shape for Z sections wheel rim at 100 rad/s.**



**Fig. 6. 1st mode shape for I sections wheel rim at 100 rad/s.**

Minimum natural frequency for Z section wheel rim is 4.58 Hz at 500 rad/sec velocity and maximum natural frequency is 11.69 Hz at 100 rad/sec for aluminum alloy material. Minimum natural frequency for I section wheel rim is 5.59 Hz at 500 rad/sec velocity and maximum natural frequency is 16.45 Hz at 100 rad/sec for aluminum alloy material. Figure 4 shows the variation of natural frequencies for five angular velocities with Z and I section wheel rim. X axis contains angular velocity of wheel rim in rad/sec and Y axis contains natural frequencies in Hz.

**TABLE 3: Equivalent Stress (Mpa) and Total Deformation (mm) by Static Analysis**

Results	Z-Section	I-Section	% Difference
Equivalent Stress (Mpa) for Single Passenger	0.8615	0.6635	22.98
Equivalent Stress (Mpa) for Double Passenger	1.1535	0.8883	22.99
Deformation (mm) for Single Passenger	0.0032	0.0023	28.12
Deformation (mm) for Double Passenger	0.0043	0.0030	30.23

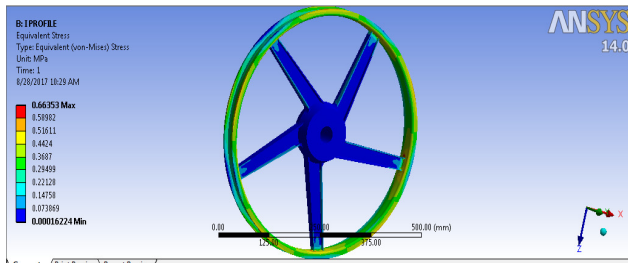


Fig. 7. Equivalent stress for I section spokes( 1 seated)

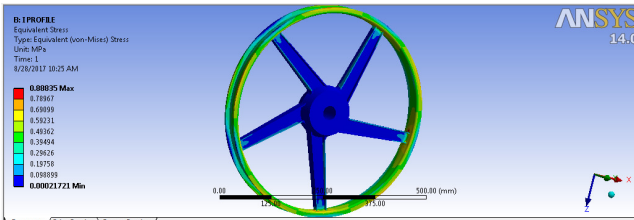


Fig. 8. Equivalent stress for I section spokes( 2 seated)

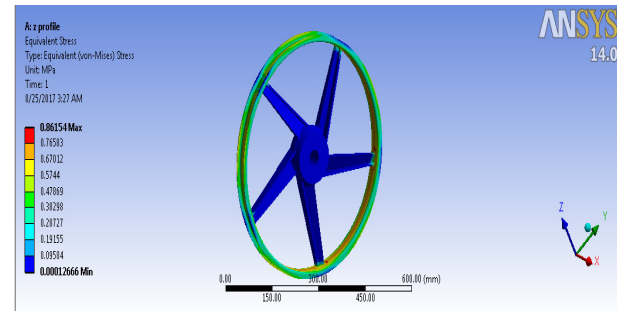


Fig. 9. Equivalent stress for Z section spoke(1seated)

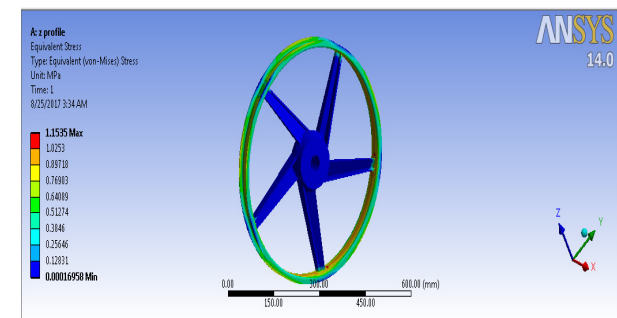


Fig. 10. Equivalent stress for Z section spoke(2seated)

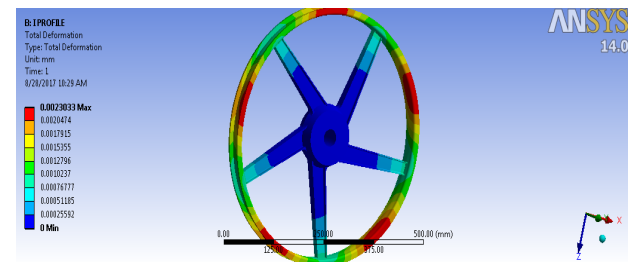


Fig. 11. Total deformation for I section spoke(1seated)

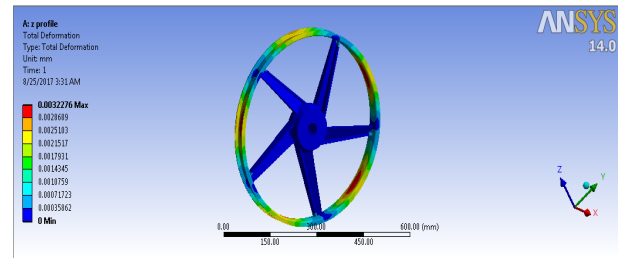


Fig. 12. Total deformation for Z section spoke(1seated)

The Equivalent stress results of aluminum alloy wheel rim with Z and I section spokes design are shown in Fig 7, 8, 9, 10,. Difference between the values of total deformation for both loading conditions is 28.12% and 30.23 % respectively. Figure 11 and 12 shows the Total Deformation for the I and Z section spoke wheel rim of aluminum alloy. The calculated weights are shown in Table 4. The volume of I and Z section wheel rim calculated by the Creo2.0 software, the mass density of aluminum alloy is 2.67 gm/CC. The total volume of Z section wheel rim is 1469492 mm³ and for I section 1343025 mm³.

TABLE 4: Weights of the Wheel Rim for both sections

Material	Wright of Wheel Rim (Z section)	Wright of Wheel Rim (I section)	% Difference
Aluminum alloy (356.0-T61)	3.92 Kg	3.58 Kg	8.67

## 5. CONCLUSION

Based on the results obtained for Static structural analysis, it is observed that I section wheel rim is better than the existing Z section wheel rim design. The weight of aluminum alloy wheel rim for Z section and I section is found to be 3.92 Kg and 3.58 kg respectively. Thus introducing I section in the manufacturing of wheel rim, the weight of wheel will be reduced by 8.67 %. This weight reduction will increase fuel economy and handling of the vehicle.

The reduction of weight will be 0.34 Kg, so this much amount of material will be saved during manufacturing of single motorcycle wheel that also causes cost reduction. This means the raw material cost of aluminum alloy wheel rim is found to be less as compared to existing wheel rim.

Further investigation can be performed for various designs to get better performance of wheel rim. The material reduction can be done by reducing a number of spokes. Damping property like wire spoke wheel, will be added with these lighter alloy wheel materials.



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# Enlarging Practice of Anomaly Detection Systems with Data Analytics Technique as Data Mining: Survey

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**Abstract:** Inspite of major evolution in anomaly detection techniques, more defensive techniques need to protect network against modern attacks. Analytical techniques such as data mining used to monitor performance of network traffic, port activity. These analytics used to find a pattern in the data which used to detect malwares practice, abnormal behavior from stored baseline of normal behavior. This paper presents a survey of such data analytics practice like data mining for anomaly detection in a network flow.

**Keywords:** Anomaly Detection, Data Mining, Clustering, Classification

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## 1. INTRODUCTION

As dependence on the network has been moving vastly, more defensive a safe and sound, steady and efficient network is essential for today's society. So, different analytics techniques used to supervising the real time network internationally and timely to make sure the network running regularly.

Intrusion detection systems has received a lot of attention towards monitoring security threat. These can be classified into signature based detection (SD), anomaly detection (AD) ( Hung-Jen et al., 2013). A signature is a pattern or string that relates to a previously identified attack or threat .SD is the process to compare patterns or traffic or application data against normal defined behavior for distinguishing probable intrusions. In addition, maintaining the signature database and labeling the patterns is time consuming and expensive (Miller et al., 2011).Snort and Bro are a SD systems(Roesch, Martin 1999; Paxson, Vern, 1998). Anomalies are considered in different aspect as outliers, aberrations, exceptions, or peculiarities ( Chandola et al., 2009).AD refers to storing features of user's usual behaviors into a database, then find a deviation of current users behavior with established behavior If huge deviation will found, it produce an alarm, as it detect something is abnormal.

Anomaly detection is an application of a Data analytics such as data mining. Various data mining techniques are used to detect an intrusion in a network flow (Viktor, et al., 2017). Data mining plays a vital role in knowledge discovery in various domains like medicine, finance, economics .In addition to this data mining and its techniques has been explored more effectively to identify hidden information, different patterns from high dimensional traffic from network flow (Iwan et al., 2012).

These patents, facts, information can be used to detect an anomalies in a network.

In this view, this paper introduce a survey of different approaches of anomaly detection systems focuses on data analytics as data mining. Data mining has different task like clustering, classification etc.

## 2. DATA MINING

Data Mining is basically extracting of ignored, hidden, earlier unidentified and potentially useful information from enormous network flow. In other words, It sometime called as knowledge discovery process of knowledge mining, knowledge extraction or data /pattern analysis(Sushil et al., 2012; Prashansa, 2015; Bharati, 2016) . There are major techniques like classification, clustering, sequence pattern etc. are used in knowledge discovery process. The objective of this technique is to discover a hidden, explicite patterns that were earlier unknown. . Data mining techniques are attractive as they can be applied to any kind of data in order to learn more about hidden structures and correlations, so, they can further be used to many application like anomaly detection (Bharati, 2016) .

### 2.1 Data Mining Techniques

**Classification:** It is a data mining function that assigns items in a collection to target categories or classes. A classification task begins with a data set in which the class assignments are known.

**Clustering:** Clustering can be said as identification of similar classes of objects. By using Clustering techniques we can further identify dense and sparse regions in object space and can discover overall distribution pattern and correlations among data attributes. Classification approach can also be used for effective means of distinguishing

groups or classes of object but it becomes costly so clustering can be used as preprocessing approach for attribute subset selection and classification. For example, to form group of customers based on purchasing patterns, to categories genes with similar functionality.

**Sequential patterns:** to determine similar patterns in data transaction over a business period. The discover patterns are used for further business analysis to recognize relationships among data.

### 3. ANOMALY DETECTION

AD in Intrusion Detection system is recognized internationally due to its flexibility to update its behaviour of the network flow as it has capability to find a new modern attacks. It's a very critical task to fix any predefined rule for recognizing correctly attacks. Ad intrusion system, it states finding hidden patterns in network flow that defer from stored behavior of users network flow and alarm an attack if there is abnormal behavior of network flow.

Anomaly detection has been the topic of a number of surveys and review articles, as well as books. Hodge and Austin provide an extensive survey of anomaly detection techniques developed in machine learning and statistical domains(Hodge and Austin, 2004). A broad review of anomaly detection techniques for numeric as well as symbolic data is presented by Agyemang (Agyemang et al., 2006). An extensive review of novelty detection techniques using neural networks and statistical approaches has been presented (Markou and Singh, 2003). A survey of anomaly detection techniques used specifically for cyber-intrusion detection is presented by Patacha (Patacha and Park, 2007). A substantial amount of research on outlier detection has been done in statistics and has been reviewed in several books as well as other survey articles..

By considering a collection of a data set, anomaly detection system (ADS) can be classified as host-based and network-based (Sushil et al., 2012).

- **Host Based ADS:-** ADS model evaluate on system which is being overserved. Collected data is in term of different host activities like records of OS, system logs, application program information, and so on.
- **Network Based ADS:-** ADS system is evaluated on the network which is near to system being observed. It inspect the real time network flow and recognize whether traffic have any hidden pattern which defer from normal behaviour. Collected data is in term of Internet packets.

#### 3.1 Anomaly Detection Techniques:

Based on the extent to which the labels are available, anomaly detection techniques can operate in one of the following three modes ( Patcha and Park, 2007).

##### *Supervised anomaly detection:*

*Models* in supervised mode have consider the availability of a training data set which is labelled normal as well as anomaly class. These models are static or predictive models. Issues that arise due to imbalanced class distributions have been addressed in the data mining and machine learning literature .

##### *Semi-Supervised anomaly detection:*

Models in a semi-supervised mode, consider that the training data has labelled instances which is labelled only as a normal class. A limited set of anomaly detection techniques exist that assume availability of only the anomaly instances for training.

##### *unsupervised anomaly detection:*

Models in unsupervised mode does not need training data, and thus they are mostly used for any type of applications. Such a technique have a assumption that instances which are frequent are considered as a normal.

### 4. ANOMALY DETECTION USING DATA MINING TECHNIQUES

Data mining introduce a different technologies which can help improve intrusion detection by finding a different rules, hidden patterns, different characteristics of information any huge amount of data.

- 1) It handle any high dimensional data
- 2) Establish a relation between data and its attribute
- 3) Analyze data and find a real attack
- 4) Identify activity which is anomalous and not covered in real attack.
- 5) Recognize long, ongoing patterns (different IP address, same activity)

Data mining has been known to aid the process of Anomaly Detection and the ways in which the various techniques have been applied and evaluated like classification, clustering, outlier detection, SVM etc. Following Table1. gives an observation from different authors for AD models with data analytics in term of data mining techniques, pros and cons of model. It will benefited to construct any hybrid model or any researcher for further modification in this area.

**TABLE 1: Summary of literature review**

Sr. No	Author Name	Data Mining Technique	Advantages	Limitations
1.	(Amuthan et al., 2012)	K-Means Clustering, C4.5 Decision Tree algorithm	It is benefited to detect the anomalies presented in the supervised data set.	1)Accuracy is not 100% 2)Not suited for training dataset which is not labeled
2	(Lahrache et al., 2017)	K-means clustering, support vector machine	A condition monitoring procedure to assess the technical condition of a Cutting blade.	1) A specific to certain type of dataset. Not used for unsupervised training data.
3	(Iwan et al., 2012)	Nearest Neighbour (NN) classifier. Principal Component Analysis	Gives a best dimensionality reduction algorithm which reduces the computational cost while still maintains the accuracy.	Time complexity is high.
4	(Dokas al., 2002)	Outlier detection, SVM	1)More successful in detecting network attacks than standard data mining techniques 2) High performance for on-line and distributed intrusion detection	Not applicable for security aspects including prevention from cyber-attacks, and recovery from them
5	(Farid et al., 2010)	Bayesian classifier and decision tree	Algorithm achieved high detection	Require improvement in accuracy.
6	(Chitrakar and Chuanhe, 2012)	SVM classification and kmedoids Clustering	High detection rate	Time complexity high
7	(Mohammad Wazid)	Entropy for supervised way. k-Medoids clustering	1) Hybrid anomaly exists in the wireless sensor network. 2)Method is capable of finding the blackhole nodes and misdirection nodes j	Not work for attacks like sink hole, grey hole and other attacks in the network
8	(Fu, Liu and Pannu, 2012)	One Class and Two Class Support Vector Machines (In cloud computing)	1) Previous history is not required to run a model. 2) Easily udate a model by considering observed failure events.	100% accuracy is fault detection is not achieved.
9	(Farid, Harbi, and Rahman 2010)	Naive bayes and decision tree for adaptive intrusion Detection	Model helps to reduce false positives improve detection rates.	False Positive rate and remote to user attacks identification need to improve.
10	(Yasami and Mozaffari, 2009)	k-Means clustering and ID3 decision tree learning Methods	Overtakes the individual k-Means and the ID3.	Not applicable for all type of real time dataset.
11	(Hanumantha, 2011)	k-Means clustering and ID3 decision tree learning Methods	1)Help to identify anomalies from supervised and unsupervised complex dataset 2) Problem of high false alarms is solved.	Time required is a major problem.

Sr. No	Author Name	Data Mining Technique	Advantages	Limitations
12	(Viktor et al., 2017)	Random Decision forest (RDF) and multilayer perceptron (MLP) classifier.	Time required is minimized and resource consumption prob is solved	Applicable to fix type of dataset
13	(Senthilnayagi et al., 2013)	Genetic algorithm and classification algorithm	Classification is done fastly and reduction in false positive rate.	It is used for known attacks not applicable for any type of network flow.
14	(Burbeck and Nadjm, 2004)	Aggregation techniques	Its implement fast, scalable and adaptive anomaly detection	Require vast amount of specific domain knowledge
15	(Jakhale, 2017)	K-means clustering and sequence pattern	Give advantages in high accuracy, find DOS type attacks.	Time complexity large.

## 5. FINDINGS AND SUMMARY

Data mining plays a more vital role in different anomaly detection models. Most of the validation, experiments is done on KDDcup 99 intrusion dataset. However, efficiency of different models is evaluated on real-time network flow. Followings are some issues identified in this domain.

- 1) Most of the ADS systems experiment on a wired network flow. Conventional systems are inadequate for both wired and wireless network. This paradigm needs to explore in a new ADS systems.
- 2) Validation of different ADS system is applicable for fixed type of database. It leads to high detection rate.
- 3) Large number of systems experiments on KDDcup 99 intrusion dataset. This dataset is very old for consideration with new defensive systems for modern attacks. Dataset need to be updated.
- 4) Time complexity is more in some of system. So, need to focus on which techniques are suitable for any type of high dimensional and mixed type of dataset.
- 5) Data mining techniques like clustering and classifier require to be faster and scalable for a better accuracy rate.
- 6) Dealing with varying network flow remains a terrifying problem to address.

As Anomaly detections is vibrant domain in research work. These findings will help for a researcher. It's challenging to deal with a dynamic network flow and modern attack profiles.

To address all these issues, we present a comprehensive survey of incremental approaches for network anomaly detection.

## 6. CONCLUSION

This Paper discuss about different data mining techniques which have been introduced in previous years for anomaly detection system models. Anomaly detection system have ability to model the normal operation of a system/network and detect deviations from them. Although various type of research has done on Anomaly detection, more precise system should be explored by considering high dimensional network flow, high accuracy, and low false alarm rate. From above observation, Data mining techniques used for incremental network anomaly detection lies in dynamic profile updation for both normal and attack, reduced memory utilization, faster and higher detection rate, and improved real time performance of anomaly detection model. In addition, hybrid models can be fulfill effective accuracy with combination of different data mining techniques.

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# Design of ABS (Acrylonitrile Butadiene Styrene) Material Based Component and its Analysis for Mold Flow Conditions

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**Abstract:** Injection Molding is used to manufacture the plastic component by using specific processing parameters and order to set the processing parameters operator has to select based on their experience or trial and error process which is somewhat risky and complicated. This process becomes inadequate and impractical for complex products. This work reveals the design & analysis of a plastic Part using Pro-E 5.0 Wildfire i.e. Timer Knob Base to optimize an injection molding parameters are optimized to reduce cycle time & defects. Mold flow analysis software is a simulation tool to locate feed & gate location also predicts the defects in the component. To select the optimum processing parameters this work gives the result of fill analysis, pack analysis, and cooling analysis which is beneficial to select the optimum processing parameters.

**Keywords:** Timer knob base, Acrylonitrile butadiene styrene (ABS), Mold Flow Plastic Expert (MPX), cycle time.

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## 1. INTRODUCTION

Thermoplastic injection molding is a process utilized for the manufacturing of the simple as well as complex plastic parts. This system has been a challenging process for manufacturers to meet required product with all the specifications & quality at the minimum cost.

In this process the main focus should be on the improvement of the quality product with minimum cycle time, lower production cost means ultimately indirect effect on the expected profit for companies with injection molding process. Some of the manufacturers are able to meet the required quality characteristic under the acceptable limits by keeping favorable process parameters by using their experience or trial and error method which is not accurate as such.

In general at the time of manufacturing of plastic components there are many defect may be occurs such as sink mark, blow holes, dimensional changes, incomplete filling etc. These defects can be reduced or eliminated by selecting optimum processing parameters such as melt temperature, mold temperature, injection pressure, cooling time, velocity, value and time of packing pressure etc. as ideal conditions for manufacturing along with improvements in productivity of a process. It is able to find these process parameters by optimization technique. The research is deals with the use of Mold flow Plastics expert (MPX) system for real time study of the timer knob base previous to the manufacturing by analyzing the parameters which afterwards used for actual production on injection molding.

## 2. METHODOLOGY

Methodology employed for the successful conduction of experiments is explained by the flow diagram as below Designing of the Component (3D model) by using tools i.e. Pro-E

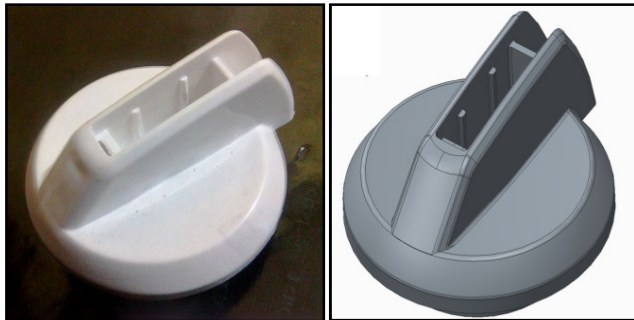
1. Identification of the features that would be used for special elements at the time of designing the mold.
2. Import Step file of 3D Model in Mold flow software.
3. Parametric Combinations / Design of Experiments
4. Analyze the component design for suitability with molding process by Mold flow Software.
5. Modification & Suggestion in the mold design conditions accordingly.
6. Design validation of product with Mold for Optimum cycle time, dimensional accuracy, quality & surface finish, etc

## 3. DESIGN AND MODELING

The first step is design a prototype of Timer Knob Base. Timer Knob Base is part of Washing Machine, which is fitted at Top fender washing Machine for the Timer Setting of adjustment. There are some requirements for designing Timer Knob Base such as hardness and deformation could be suitable with practical conditions, Thickness of product is also affects directly to the product quality and its prices. By increasing thickness which will require more cooling time, decreased productivity, and some defects such as

bubbles, shrinkage, etc. Therefore, the balance of thickness is extremely important step; the thickness of designing process is about from 0.9 to 6.4 mm.

Combining requirements and using Pro-E software 5.0 Wildfire, a model of Timer Knob Base was constructed as in fig. 2



**Fig. 1. Timer Knob Base –Designed & Manufactured**

#### 4. COMPONENT DETAILS

- Volume of model: 116.45 mm³
- Surface area of model: 1324.12 mm²
- Weight of component: 12.11 grams.
- Number of cavity: four cavities
- Minimum and maximum wall thickness: 2mm & 0.7mm
- Type of mold: Two plate mold.

#### 5. MATERIAL DETAILS

- Material=Polymer : Absolac 100 : Styrolutione (ABS)
- Density of ABS = 0.104 g/mm³
- Specific heat (Cp) = 1963.0000 J/kg-C
- Thermal conductivity = 0.1400 W/m-C

#### 5.1 Analysis & Experimentation

##### Mold Flow Conditions

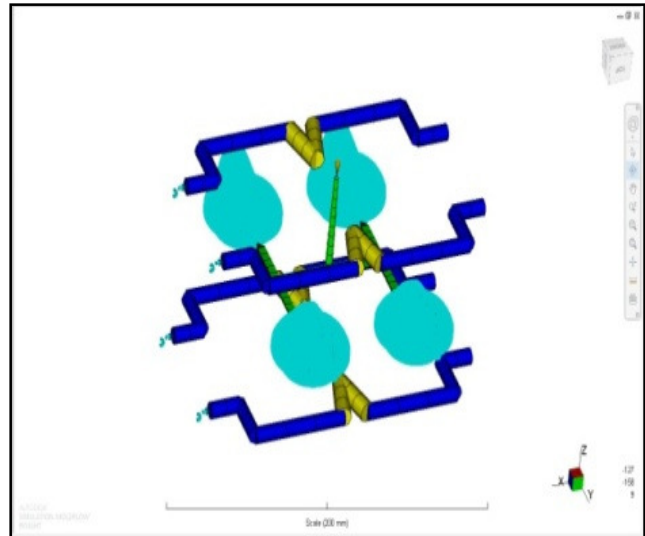
The Mold flow Analysis for the component & multi cavity as per the product design by using mold flow Expert software.

The Following are the conditions are used to analyze the component along with process parameters setting

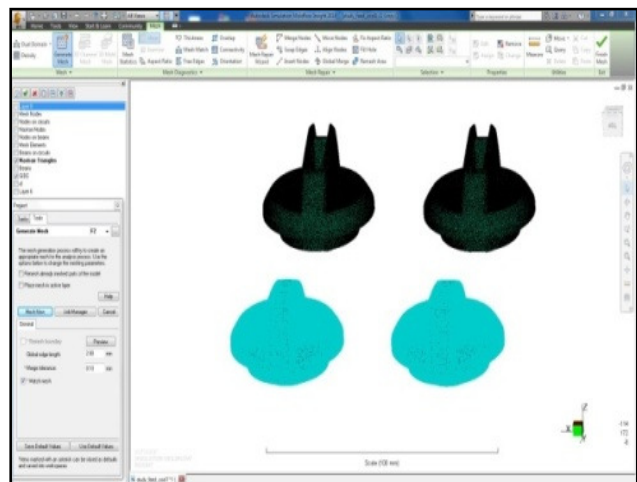
##### Meshing -

Analyzing a model is a very complex operation also modeling of a non-Newtonian fluid like molten plastic flows through complex model geometry is difficult. As a

consequence, a part is divided into smaller joined elements. The result is a mesh.



**Fig. 2. Meshed component without feed system**



**Fig. 3. Component with feed& cooling system**

##### Injection locations & Feed system –

The injection & feed system location is the position where molten plastic is injected, enabling the software to simulate the flow pattern inside the mold cavity as required. This gives the considerations affecting the selection of injection locations when running a Fill + Pack + Cool analysis.

##### Cooling System

The cooling circuit is consisting of the cooling channels, various mechanisms added to the cooling channels to make possible cooling, and the coolant which flows through the system. In general requirement for cooling the part will always be a homogeneous cooling such that part quality, and fast cooling to reduce production cost.

### 5.2 Design Of Experiment -

Design of Experiment is a systematic approach for evaluating the relationship between the input factors & quality criteria using statistical methods. DOE analysis will provide you with information about the sensitivity of the input parameters about a given part design

### Variable Influences (Taguchi) -

Variable Influences is the suggested experiment to run if unsure about the variables to monitor. The DOE solver launches an optimized set of analyses to resolve this ranking, can select as many input variables as required for this experiment.

**TABLE 1: Factorial Design Matrix**

Factors	Level		
	Min.	Mid.	Max.
A. Melt temperature (C)	240	260	280
B. Mold temperature C)	40	60	80
C. Injection time (s)	0.8	1.0	1.2
D. Cooling time (s)	16	20	24
E. V/P switch over by % volume filed	98	99	100
F. Coolant inlet temperature ( $^{\circ}\text{C}$ )	25		

An analysis can also be launched from the command line using a utility called **run study**, which is installed with the software.

**TABLE 2: Summery of Result for Responses**

Trial No / Runs	Variables / Parameters					Responses		
	A	B	C	D	F	Sink mark depth	Volumetric shrink	Total part wt.
Units	$^{\circ}\text{C}$	$^{\circ}\text{C}$	s	s	%	m	%	kg
0	240.15	40.15	0.8	16	98	0.00013911	1.33069	0.0520931
1	240.15	40.15	1.2	24	100	0.00013168	1.32615	0.0522032
2	280.15	40.15	0.8	16	100	0.00010077	1.44846	0.0526397
3	280.15	40.15	1.2	24	98	0.00010682	1.44539	0.0525957
4	280.15	80.15	1.2	16	98	0.00015965	1.46222	0.0518039
5	280.15	80.15	0.8	24	100	0.00015298	1.48143	0.0518698
6	240.15	80.15	1.2	16	100	0.00012509	1.26351	0.0522529
7	240.15	80.15	0.8	24	98	0.00012819	1.27485	0.0522265

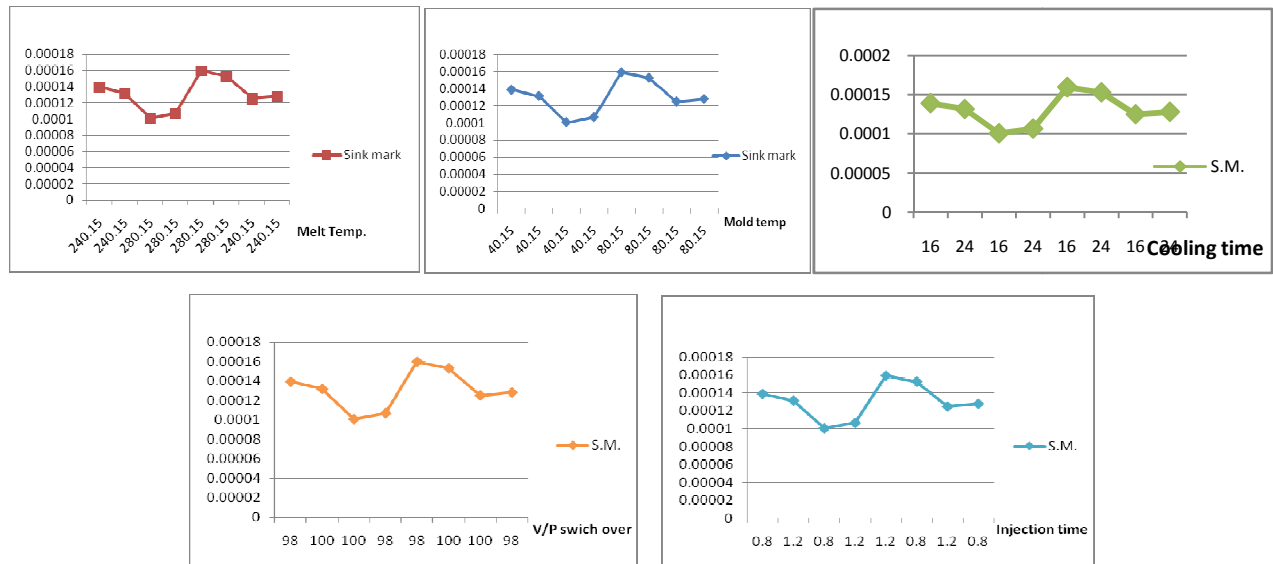
### 5.3 Analysis Of Result

#### Sink Mark Depth –

Fig.7 shows the response diagram for sink mark. Based on this figure, it can be easily to indentify the optimal parameters. In this case the response smaller is better. Selecting the lowest value among each point could identify these optimization levels.



**Response: Smaller is better**



**Fig. 4. Response Diagram for sink marks**

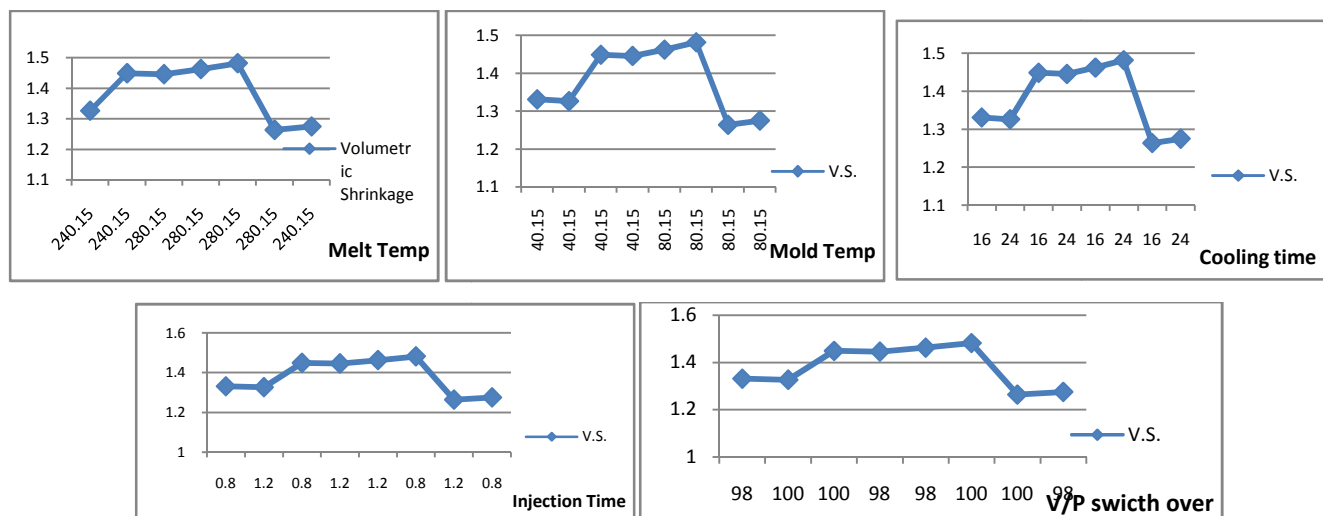
The recommended setting result of sink marks was produced by a combination of A3, B1, C1, D1, E3 as shown in table III.

**TABLE 3: Optimum setting for sink marks**

Parameters	Melt temperature (°C)	Mold temperature (°C)	Cooling Time (s)	Injection time (s)	V/P switch over by % volume filed
Optimum Level	280	40	16	08	100

**Volumetric Shrinkage–**

Fig 05. Shows the response diagram for Volumetric Shrinkage. Based on this figure, it can be easily to indentify the optimal parameters. In this case the response smaller is better. Selecting the lowest value among each point could identify these optimization levels.



Response – Smaller is Better

**Fig. 5. Response Diagram for volumetric Shrinkage**

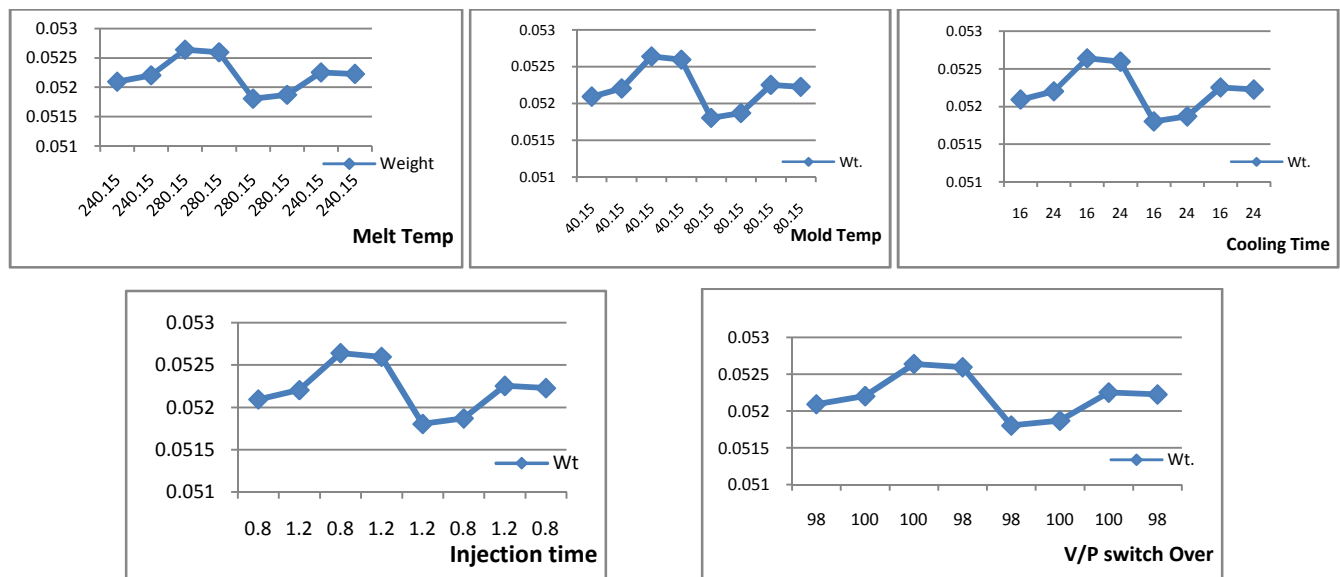
The recommended setting result of volumetric Shrinkage was produced by a combination of A3, B3C1, D3, E3 as shown in table IV.

**TABLE 4: Optimum Setting for Volumetric Shrinkage**

Parameters	Melt temperature (°C)	Mold temperature (°C)	Cooling Time (s)	Injection time (s)	V/P switch over by % volume filed
Optimum Level	280	80	16	1.2	100

**Product Weight –**

Fig 6. Shows the response diagram for Product weight. Based on this figure, it can be easily to identify the optimal parameters. In this case the response Close to 0.0520 is better. Selecting the lowest value among each point could identify these optimization levels.



Response – close to 0.052 is better

**Fig. 6. Response Diagram for Product Weight**

The recommended setting result of product weight was produced by a combination of A3, B3C3, D1, E3 as shown in table V.

**TABLE 5: Optimum Setting for Product Weight**

Parameters	Melt temperature (°C)	Mold temperature (°C)	Cooling Time (s)	Injection time (s)	V/P switch over by % volume filed
Optimum Level	280	80	24	0.8	100

After getting all the results, the final optimum parameters should be responsible for all the response together for the defect free product along with required dimensions.

So consider average of the optimum parameters of all the three responses for virtual and experimental calculations.

**TABLE 6: Optimum Setting for Virtual & Experimentation**

Parameters	Melt temperature (°C)	Mold temperature (°C)	Cooling Time (s)	Injection time (s)	V/P switch over by % volume filed
Optimum Level	260 - 280	60	19	1	99

#### 5.4 Processing Parameters For Mold Flow Analysis -

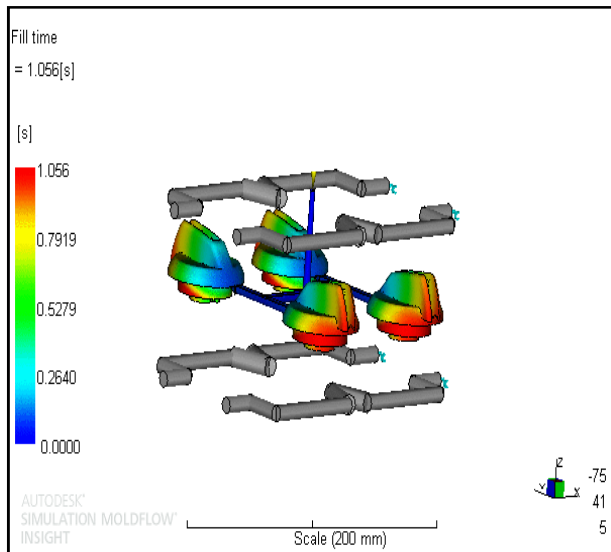
While Performing Fill+ pack + Cool Analysis to get the Optimize gating, Optimize runner system , Visualize shear stress, forecast fill pattern, temperatures, injection pressure, volumetric shrinkage, sink, Determine venting Avoid air traps etc

### 6. RESULTS AND DISCUSSION

A result summary showing the analysis inputs and the results of each phase of the analysis or analysis sequence was generated for each analysis that has performed. The Logs section reports various text results that relate to the analysis or analysis sequence. For specific information on a particular analysis, check the various Analysis Logs. For a Fill+ Pack + Cool + Warp analysis, the following results are recorded to investigate the simulation.

#### 6.1 Optimized Fill Time

The fill time of the component when using ABS material has analyzed. The fill time results gives the position of the flow front as the cavity fills at regular intervals. Each same color represents the parts of the mold which were being packed at the same time.

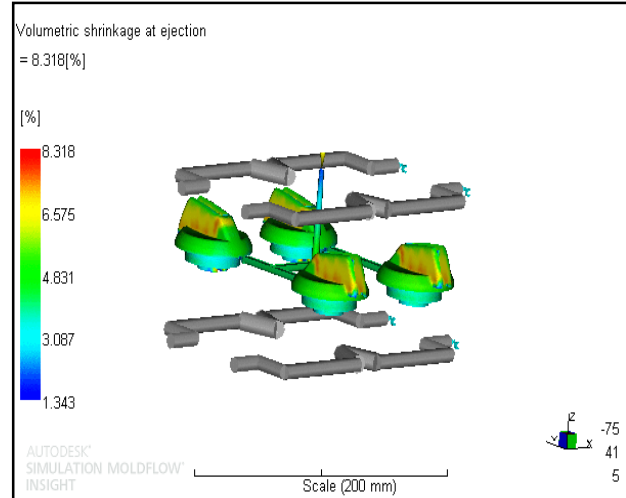


**Fig. 7. Optimized Fill time**

Comments: Fill plot shows uniform filling. The entire farthest region receives material at same time. Balanced flow throughout filling is observed.

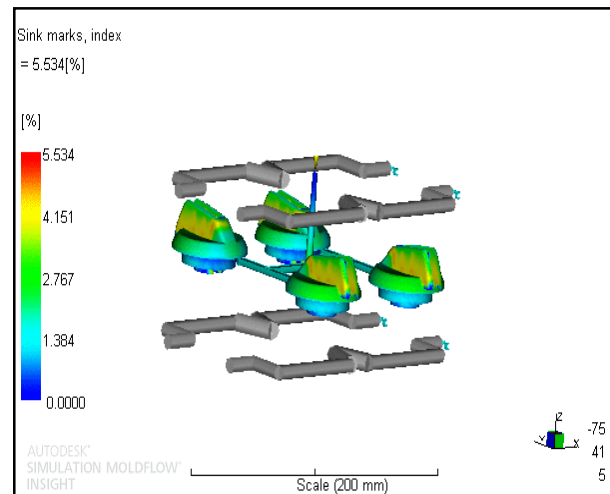
#### 6.2 Volumetric Shrinkage At Ejection

Comments: - It shows Volumetric shrinkage at ejection i.e. 4.665 % which is within the acceptable limit



**Fig. 8. Volumetric Shrinkage at Ejection**

#### 6.3 Sink marks



**Fig. 9. Sink marks, index**

Comments: - It shows Sink marks, index i.e. 2.11 - 4.1% which is within the acceptable limit.

The Sink marks, index is an sign of the shrinkage due to a hot core at different positions. It has calculated for each constituent at the time when local pressure has rotten to zero during the packing stage, and reflects how much material is still melt and left unpacked.

#### 6.4 Experimentation

In order to meet the objectives mentioned experimentation is carried out according to design of experiments technique.. This chapter flourishes all the details including process parameters along with the following

- Injection Molding machine
- Molding Tool
- Product material
- mold flow software

### Injection Molding Machine

Choosing type of machine is always the first step before fabricating any products. For this work, JIT-D 160/600 machine is applied to manufacture a proposed plastic Timer Knob Base.

### Molding Tool

For this experiment the molding tool is made up of in two different half along with ejection system i.e.

1. A Fixed mold half from where plastic is injected
2. A moving type of half on ejecting side.

### Design Calculation For Tonnage Of Mold -

- i) Volume and Weight of Timer Knob Base -

Volume of the component (from Pro-E model) = 116.45 mm³

Density of plastic material (ABS) = 0.104 g/mm³

Weight of the component = Volume X Density = 116.45 X 0.104 = 12.11 g

ii) Shot weight -

Shot weight of the mold = Total weight of the component + Total weight of the feed system

Total weight of the component = (weight of component x No. of cavities) = (4 x 12.11) = 48.44g

Total weight of the feed system = 8% of the component weight = [(8/100) x 48.44] = 3.87 g

Thus the shot weight of mold = (48.44+3.87) g = 52.11 g.

## 7. VALIDATION

The validation of components design & process parameter is done by producing it. Quality, defects along with the Dimensional accuracy is measured and checked with the particular dimensions by using different instruments & method in the inspection laboratory at CIPET, Aurangabad. The following are the readings recorded during the inspection.

**TABLE 7: Dimension of sample**

Parameter	Specified size (mm)	Test sample 1 Reading	Test sample 2 Reading	Test sample 3 Reading
Overall Length	53.5 (+/-0.4)	53.14	53.27	53.27
Breadth	48.4 (+/-0.2)	48.20	48.20	48.25
Overall Height	34 (+/-0.2)	33.87	33.89	33.90
Thickness (Outer flange)	2 (+0.1/-0.1)	2.01	2.00	2.01
Thickness (Middle flange)	1 (+0.1/-0.1)	1.01	1.01	1.01

**TABLES 8: Comparison between results obtained by mold flow analysis software and physical experimentations.**

Sr No	Description	Reading (MPX)	Reading (Exper)	Remarks
1	Sink Marks Index	2.11 4.1%	Visual aid used for checking didn't record any significant mark	Sink marks are within the acceptable limit
2	Volumetric shrinkage	4.66 %	3.33 %	Accepted level of shrinkage as applicable
3	Melting Temp	220	227-229°C	Good match over the result
4	Total Weight (part + runners)	52.11 g.	51.9472 g	The reading of test samples is very closer to the specified
5	Total Weight of Component	12.11 g	11.7077 g	Weight of single part is found to be within acceptable limits
6	Fill time	1.056 sec	1.76 Sec	The fill time is nominal & do not pose any problem
7	Cycle time	35.00 s	37.27 s	Good match over the result
8	Processing Temp	242-261 °C	Zone 2 - 230 °C +/- 40°C Zone 3 - 220°C +/- 40°C Zone 4- 220 °C +/- 99°C	Good match over the result
9	Cooling time	25 Sec	30 sec	Good match over the result

## 8. CONCLUSION

Starting from the Design along with analysis of the wide state-of-the-art and scientific literature, methods and tools are selected, speed and results accuracy which finally concludes as follows:

- The product was manufactured using the in-house tool room facilities according to standards specified by the organization
- High quality product achieved by Using the Autodesk Moldflow Insight.
- The dimensions & defects of the Components are checked by testing tool which are within the acceptable limit.
- Due to cooling channel has provided in the molding tool, no flash mark, no blow hole defect, or flow line defects occurred during the production of Timer knob base.

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# Tribological Investigation of Al6061/SiC/B₄C Hybrid Nano Metal Matrix Composites and its Predictive Model using Fuzzy Logic

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**Abstract:** Conventional materials are increasingly being replaced by metal matrix composites (MMC) in engineering applications having relative motion, specially in the field of aerospace, automotive and sports industries. The current work attempts to study the effect of the different tribological parameters such as sliding distance, sliding speed and load on specific wear rate (SWR) and coefficient of friction (COF) for a hybrid nano MMC (Al 6061/SiC/B₄C). Taguchi's L₉ orthogonal array has been used for experimentation. ANOVA shows that load and spindle speed have significant effect for both SWR and COF. Fuzzy logic (FL) predictive models have been developed for SWR and COF. The prediction accuracy of the model is verified and shows an accuracy of 95.08% and 96.37% for SWR and COF respectively. The established model can aid in developing knowledgeable system for process control in industries.

**Keywords-** Wear, metal matrix composite, fuzzy logic.

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## 1. INTRODUCTION AND LITERATURE REVIEW

Tribological characterization is extremely critical for increasing performance and material life in various industrial applications demanding relative motion especially in the field of automotive, aircrafts, defense, transportation and storage devices (Bhushan, 2013). Global competition and interest for high benefits has constrained industry to reduce working expense while increasing efficiency. From the economical perspective, wear rate and friction are the most important aspects of feasibility for any industrial enterprise. Materials with suitable combination of properties are necessary for automobile, underwater, aerospace and transportation applications which cannot be fulfilled using the conventional metallic alloys, metals, ceramics and polymeric materials.

Aluminium based composites with ceramic reinforcements have been extensively used in various industries due to their superior properties like high specific strength and modulus, ease of fabrication and low cost (Dou Y. et. al., 2014). Wide acceptance of these aluminium based composites in industry can be mainly attributed to the improved wear resistance and high temperature performance. The type of hard ceramic particles, their size and shape, composition aids in tailoring the desired properties of these composites. Ceramic particles like SiC, Al₂O₃, TiC, B₄C, TiB₂, Gr both in micro and nano form have been used by researchers to enhance strength, stiffness and improve wear resistance of aluminium based composites (Manivannan I. et. al., 2017). The effects of sliding speed and SiC content were studied

on aluminium matrix composites (Rao R.N. and Das S., 2011). The alloy was found to have better wear resistance due to SiC particle addition. However, the wear rate amplified with increase in sliding speed. Friction and wear behaviors of 6061 Al composite reinforced with B₄C were investigated by varying the sliding time and velocity, normal load applied and heat treatment (Dou Y. et. al., 2014). Severe delamination was reported when the sliding time and applied load reached 120 min and 30N respectively. When the sliding velocity reached 240 r min⁻¹, fretting wear dominated resulting in mass loss and increase in coefficient of friction (COF). Tribological behavior under dry sliding condition of Al2024 reinforced with 5 wt.% B₄C nano particles were investigated (Abdollahi A. et. al., 2014). Wear test results indicate that addition of B₄C nano particles aids in increasing the hardness, strength and wear resistance of Al2024 alloy. Tribological analysis of Al6061 reinforced with nanometric SiC was investigated (Manivannan I. et. al., 2017). Al6061-SiC nano-composites were found to exhibit enhanced wear resistance than the Al6061 alloy.

Tribological properties of hybrid composites, which consists of more than one reinforcement has also been considered and explored by many researchers. The consequence of different reinforcements on sliding wear of Al6061 nano-composites has been investigated (Jeyasimman D. et. al., 2014). Nanometric TiC, γ-Al₂O₃ and hybrid (TiC+Al₂O₃) were used as reinforcements. Increase in sliding velocity and normal applied load, the

wear rate increased for all the nano-composites. However, hybrid ( $\text{TiC}+\text{Al}_2\text{O}_3$ ) reinforced Al6061 had lesser wear rates and coefficients of friction than the single reinforced nano-composites. Wear performance of Al6061 reinforced with (Cu+SiC) and (Cu+Gr) hybrid composites were also studied (Zakaulla M. et. al., 2015). Pin-on-disc apparatus was used to carry out the wear test. Specific wear rate (SWR) was affected by applied load and sliding speed while COF was influenced by applied normal load and sliding distance for the hybrid composites. Al6061 reinforced with combinations of Mg, fly ash and Gr hybrid metal matrix composites (HMMC) were explored (Kumar V. et. al., 2014). SWR was found to decrease with addition of fly ash and Gr up to 15% and 4% respectively.

SiC is the most common reinforcement which imparts high hardness and is chemically and thermally stable. On the other hand,  $\text{B}_4\text{C}$  has better interfacial bonding with aluminium and leads to better wear resistant. Also,  $\text{B}_4\text{C}$  is an excellent neutron absorbent and has prospective applications in nuclear industry. In the present work, Al6061 reinforced with nano-particulate SiC and  $\text{B}_4\text{C}$  were

investigated for tribological applications. Further, modeling of the tribological parameters is attempted using fuzzy logic technique for the output responses like SWR and COF.

## 2. EXPERIMENTAL DETAILS

### 2.1 Material used

HMMC comprising Al6061 as matrix and SiC and  $\text{B}_4\text{C}$  particles of 50 nm as reinforcements in the combination of Al6061+1.5% SiC +1.5%  $\text{B}_4\text{C}$  has been prepared using conventional stir casting route and is used for the experimentation.

### 2.2 Experimental procedure

Pin-on-disc tribometer was used to carry out the wear test under dry conditions at room temperature. Rectangular pins of dimensions 10mm×10mm×50mm were machined from the composites for tribological tests based on ASTM G99-05 (2010) standards. The pins were tried against an EN30 steel disc having hardness of 62 HRC and a surface finish of 2.54  $\mu\text{m}$ . The standard specimens of the tribology test and the pin-on-disc arrangement is shown in Fig.1.

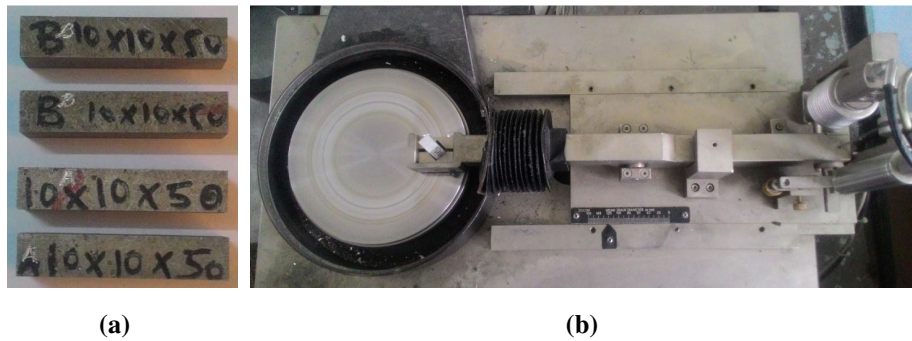


Fig. 1. (a) Test specimen, (b) Pin on disc setup for tribology test

Taguchi's design of experiments (DoE) is used to perform the wear experiments. The three input parameters and their equivalent levels used during experimentation are presented

in Table I. SWR and COF were measured as the output responses for the hybrid composite specimens.

TABLE I: Input factors and their levels

Factors	Parameters	Intensity		
		Small (-1)	Moderate (0)	Large (1)
A	Sliding distance (m)	1000	1500	2000
B	Sliding speed (rpm)	100	300	500
C	Load (N)	10	20	30

The specific wear rate (SWR) and the coefficient of friction (COF) of the test specimens are calculated as per Eq. (i) and (ii) respectively.

**TABLE II: Experimental results**

Sl. No.	Combination of factors			Output responses			
	A	B	C	SWR ( $\times 10^{-4}$ ) (mm ³ /Nm)	S/N ratio (dB)	COF	S/N ratio (dB)
1	1000	100	10	4.1	-14.3050	0.2571	11.3284
2	1000	300	20	2.6	-5.1676	0.3279	10.2571
3	1000	500	30	0.67	2.3960	0.3133	9.9785
4	1500	100	20	4.7	-14.5245	0.3244	9.6760
5	1500	300	30	0.65	1.6924	0.2643	11.0885
6	1500	500	10	5.4	-11.5160	0.2816	11.5793
7	2000	100	30	2.5	-4.8269	0.3308	10.1806
8	2000	300	10	2.6	-9.3820	0.2381	12.3625
9	2000	500	20	2.2	-8.8978	0.3137	9.6001

$$SWR = \frac{\Delta m}{\rho L F_n} (mm^3 / Nm) \quad (i)$$

$$COF = \frac{f}{F_n} \quad (ii)$$

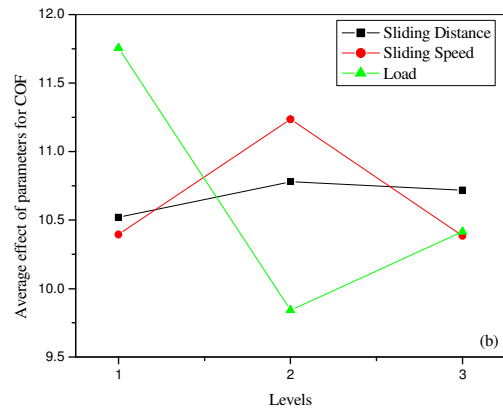
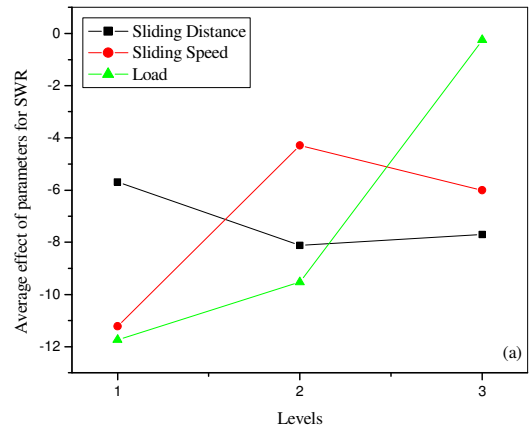
where,  $\Delta m$ =Initial_{mass}-Final_{mass} (g),  $\rho$ =experimental density (g/mm³),  $L$ = total distance travelled/ sliding distance (m),  $F_n$  is the applied normal load (N) and  $f$  is the frictional force. Taguchi's L₉ orthogonal array has been used to design the experiments. The output responses for Hybrid MMC for the 9 set of experiments is reported in Table II.

Taguchi established signal to noise (S/N) ratio to measure the deviation existing in the output responses. Improvement of the S/N ratio concurrently increases the quality characteristics and reduces the influence of noise factors. 'Smaller the better' quality characteristics are assigned for both SWR and COF and can be computed using Eq. (iii).

$$Y = -10 \log_{10} \left[ \frac{1}{n} \sum y_i^2 \right] \quad (iii)$$

where, 'y' is the ordinate of the measured response value and 'n' is the total number of experiments conducted. A larger S/N ratio resembles to improved excellence and indicates better parameters. The average effect of the input parameters and their interactions based on S/N ratio at different levels for SWR and COF is shown in Fig. 2.

Analysis of variance (ANOVA) is carried out for both SWR and COF to find the most influencing input parameters on the output responses and is shown in Table III and IV respectively.



**Fig. 2: Average effect of parameters for (a) SWR and (b) COF**



**TABLE III: ANOVA for SWR**

Factors	DOF	SS	V	FR	PS	PC
Sliding Distance	2	6.592	3.296	3.164	2.365	10.68
Sliding Speed	2	12.971	6.485	6.232	6.744	22.619
Load	2	33.953	15.976	15.367	18.726	64.732
Error	2	6.227	3.113			1.969
Total	8	59.743				100.00%
DOF: Degrees of freedom, SS: Sum of squares, V: Variance, FR: F-Ratio, PS: Pure Sum, PC: Percentage Contribution						

**TABLE IV: ANOVA for COF**

Factors	DOF	SS	V	FR	PS	PC
Sliding Distance	2	0.001658	0.00123	1.071	0.0015	12.231
Sliding Speed	2	0.003584	0.00452	3.778	0.0036	23.678
Load	2	0.006632	0.00348	9.386	0.0055	55.563
Error	2	0.002548				8.528
Total	8	0.014422				100.00%
DOF: Degrees of freedom, SS: Sum of squares, V: Variance, FR: F-Ratio, PS: Pure Sum, PC: Percentage Contribution						

From Fig. 2 and Table III and IV, it is evident that load and sliding speed are having the major contribution for minimizing both for SWR and COF for the HMMC. Sliding distance is having the least contribution for both the measured output responses. Moreover, the contribution of load is more in case of SWR (64.732%) than COF (55.563%).

### 3. DEVELOPMENT OF PREDICTIVE MODEL USING FUZZY LOGIC

Very few researchers have used fuzzy logic modeling technique in predicting tribological parameters of HMMC. Fuzzy logic model using large number of data sets becomes costlier in practice and hence in the present work, few experimental data sets (9 sets) are used to develop the model. A typical fuzzy logic unit consists of a fuzzifier, a fuzzy rule base, an inference engine and a defuzzifier. The input variables are fuzzified into three subsets as high (H), medium (M) and low (L) while both the output responses i.e., SWR and COF are fuzzified into five subsets as very bad (VB), bad (B), average (A), good (G) and very good (VG). Gaussian and triangular membership functions are used to define the input and output parameters respectively.

In a fuzzy model, the relationship between the inputs and the outputs is categorized by a set of linguistic tributes called as fuzzy instructions. Nine set of instructions were constructed centered on actual experimentation for both SWR and COF and simulated using MATLAB 14. Mamdani type fuzzy inference system (FIS) is employed in

the present study. A de-fuzzifier is used to convert all the fuzzy output into a non-fuzzy value. Centroid of area (COA) based on centroid calculation is used as a defuzzifier.

#### 3.1 Effect of the tribological parameters on SWR

The variation of the input parameters on SWR is studied using 3-dimensional plots from FIS. The relationship between the input parameters and SWR is shown in Fig. 3. Increase in the applied load tends to fracture the reinforcement particles resulting in the development of wear. The presence of nano particles in the HMMC has been able to withstand the wear at higher normal loads. This may be due to the reduced area of contact between the surface projections of the flat surfaces. Also, higher sliding speed have resulted in lower SWR for the HMMC. This may be due to the existence of SiC and B₄C particles resisting micro softening of the matrix material at high interface temperatures during sliding.

#### 3.2 Effect of the tribological parameters on COF

The variation of the input parameters on COF is shown in Fig. 4. COF of the HMMC is less at lower values of applied load. The presence of SiC and B₄C particles have resisted the deformation of the transfer film during sliding which becomes stable for larger sliding distance over a wide range of applied normal load. Also, the COF decreases with increasing sliding speed for the HMMC.

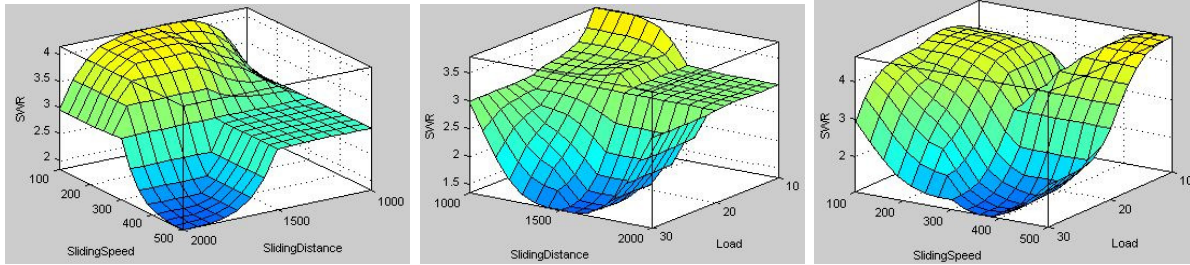


Fig. 3. Effect of input parameters on SWR

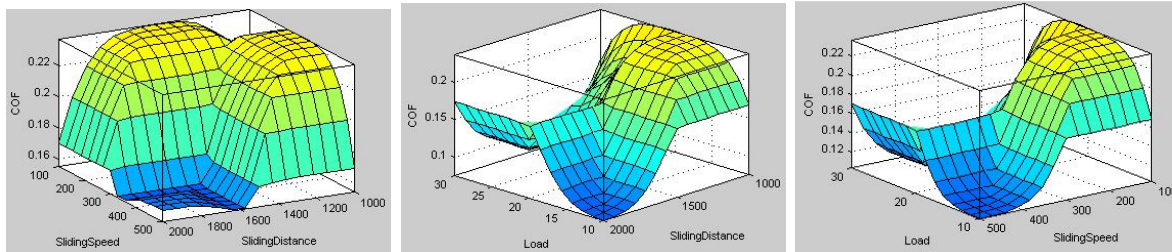


Fig. 4. Effect of input parameters on COF

### 3.3 Validation of the predictive model

The predicted FL model based SWR and COF are compared with the experimental values. The minimum, maximum and average error for SWR model is found to be 0.74%, 8.46% and 4.92% respectively with model accuracy of 95.08%. While for COF model, the minimum, maximum and average error stands at 0.64%, 7.89% and 3.63% respectively with model accuracy of 96.37%. The variation between experimental and FL predicted for SWR and COF is shown in Fig. 5.

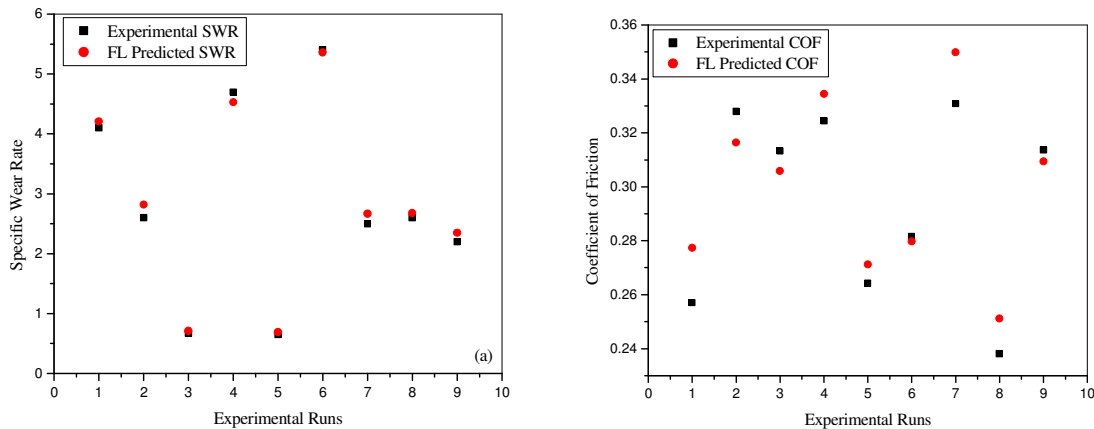


Fig. 5. Experimental vs FL predicted plot for (a) SWR and (b) COF

## 4. CONCLUSION

In this work, SWR and COF prediction model is attempted in tribological study of the hybrid nano MMC using fuzzy logic. Following are the conclusions drawn from the present investigation.

Applied load and sliding speed was found to have the most

significant effect on SWR and COF of the hybrid nano MMC. The contribution of load is more in case of SWR (64.732%) than COF (55.563%).

The presence of nano particles of SiC and B₄C in the HMMC has been able to withstand the wear at higher normal loads. Also COF reduced with increase in sliding speed.

The FL model accuracy stands at 95.08% for SWR and 96.37% for COF. The established model can aid in developing knowlagable systems for process control in industries.

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# Tribological Evaluation of Vegetable Oils as a Lubricant

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**Abstract:** Lubricants are essential for machine elements, which are important for efficient transportation, industrial production and contribute greatly to energy savings and the fuel economy. But continued increasing environmental concerns forced to increase the usage of vegetable oil utilization in lubricants for many applications. The vegetable oils offer significant environmental benefits because of its inherent qualities like high viscosity index, high lubricity, low volatility, low toxicity and high biodegradability. Also, from India's point of view, India has a great potential of producing vegetable oil based lubricants. Because of these, suitability of vegetable oils i.e. cottonseed oil and soya bean oil is checked as a lubricant. Four ball testing machine is used for experimentation as per ASTM D 4172 standard. Finally it is observed that combination of SAE 20W40 oil +10 % by vol. cottonseed oil +0.5 % by wt graphite is the best suitable lubricant.

**Keywords:** Lubricant, vegetable oil, cottonseed oil, soya bean oil, ASTM D 4172.

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## 1. INTRODUCTION

In recent years, an accidental loss of lubricant to the environment by means of evaporation, leakages, and spills. This leads to major concerns regarding to protect the environment against pollution. Also, the increased petroleum costs, decreased petroleum reserves open a route for bio-lubricant as alternatives in many applications. Also, the disposal of petroleum oils leads the problem of pollution. Due to these problems, scientists have searched for alternative products that are renewable, clean, reliable, and economically feasible. So, the replacement of petroleum base oils with biodegradable products is one of the best ways to decrease the adverse effects on both aquatic and terrestrial ecosystem caused by the use of petroleum lubricants [Anjana and Sahai, 2013, Sevim, 2005]. Vegetable oil-based bio-lubricants have a potential as alternative lubricant. The authors presented the different sources, properties, advantages and disadvantages of the bio-lubricant and the potential of vegetable oil-based bio-lubricants as alternative lubricants for automobile applications. The final part discussed about the world bio-lubricant market as well as its future prospects [H.m. Mobarak, 2014]. Vegetable oils have several properties that are required in a lubricant as a high viscosity index, high lubricity, low volatility, low toxicity and high biodegradability compared to mineral oil. Vegetable oils are a renewable resource finding their way into lubricants for industrial and transportation applications. Waste disposal is also of less concern problem for vegetable oil-based products because of their environment-friendly and non toxicity properties. Bio-lubricants can typically be made from plant oils such as rapeseed, palm, soybean, sunflower, and coconut, wax esters and plant polymeric carbohydrates [Jan, 2013].

Sachin et.al., 2014 investigated the effect of wear on M2 steel using SAE 40 oil and cottonseed oil as a lubricant. For that purpose pin on disc machine was used with M2 HSS tool. Authors studied the effect of different lubricating conditions on wear and frictional force at various sliding speed and load. Cottonseed oil was used in this research because of its low cost and availability in India [Sachin et.al., 2014]. K Balamurugan et.al studied the performance of soyabean oil as a lubricant for diesel engines. For the experimentation four ball wear test machine and diesel (single and twin-cylinder) engines were used. Diesel engines were lubed with various SBO formulations and results were compared with SAE 40 oil. From the results it was cleared that bio-degradable additives such as POME, Castor oil improve the wear resistance and oxidation stability of SBME [K Balamurugan, 2010]. N.H. Jayadas et.al evaluated the tribological properties of coconut oil using a four-ball tester and two stroke engine with and without Dialkyl-Dithio-Phosphate (ZDDP) AW/EP additive. Test results were compared with commercial lubricant SAE 20W50 oil. The results of four ball tester and test rig showed that coconut oil cannot be used in unmodified form due to higher wear rate than the 2T oil. Anti-wear and extreme pressure properties of coconut oil were improved by the addition of suitable concentration of Zinc-Dialkyl-Dithio-Phosphate (ZDDP) additive [N.H. Jayadas et al., 2007]. Iman Golshokouh et.al examined the physical properties of jatropha oil in varying temperatures and loads. Four ball tribo-tester was used for experimentation and results were compared with hydraulic oil to analyze its viability as an effective lubricant [Iman, 2013]. Kailas M. et.al., 2012 studied the physico-chemical properties such as viscosity, acid value, saponification value, iodine value of different vegetable oils and their blends. In this research vegetable oils like soybean oil,

castor oil, groundnut oil, and cottonseed oil were used for comparison [Kailas M. et.al., 2012]. Yu Su, 2015 evaluated the tribological properties of graphite nano-particle as an additive in LB2000 vegetable based oil on pin-on-disk friction and wear tester. From results it was found that graphite nano-particle improves the friction reducing and anti-wear properties of pure LB2000 vegetable oil due to formation of physical deposition film on the friction surfaces [Yu Su, 2015]. Zhenyu, 2014 studied lubricant additives based on inorganic nano-particles coated with organic outer layer can reduce wear and increase load-carrying capacity of base oil remarkably [Zhenyu, 2014]. M. Gulzar, 2015 evaluated the anti-wear (AW) and extreme pressure (EP) ability of chemically modified palm oil (CMPO) by adding nano-particles. Nano-lubricants were synthesized by adding copper (II) oxide (CuO) and molybdenum disulfide (MoS₂) nano-particles to CMPO. This study was used four-ball testing machine and sliding wear test for evaluation of anti-wear and extreme pressure properties. The MoS₂ nano-particles exhibited the better AW/EP properties than the CuO nano-particles. The addition of 1 wt % oleic acid as a surfactant facilitated the reduction of agglomerates [M. Gulzar, 2015]. Tiong Chiong, 2011 studied the lubricity characteristics of vegetable oils using four ball test machine and compared with the petroleum based oil. RBD palm olein and additive free paraffinic mineral oil were used as lubricants in this experiment. From the test results, the authors confirmed that RBD palm olein showed satisfactory performance in terms of friction reduction [Tiong Chiong, 2011]. N.W.M.

Zulkifli 2015, examined and compared the tribological properties of two lubricating oils i.e. paraffin oil and bio-lubricant which was derived from palm oil-based TMP (trimethylolpropane) ester added with TiO₂ nano-particles used as additives. Experimentation concluded that TMP ester added with nano-particles is environmentally desired to mineral oil based lubricants [N.W.M. Zulkifli 2015]. S. Syahrullail, 2013 tested the performance of oils like commercial stamping oil, commercial hydraulic oil, jatropha oil, RBD palm olein and palm fatty acid distillate as a lubricant using a four ball tribometer under extreme pressure conditions as per ASTM D2783. Results of wear scars of vegetable oil are slightly lower than that mineral oil so authors made a conclusion that vegetable oils have potential as lubricants [S. Syahrullail, 2013].

India is one of the largest oilseeds producing country in the world. Thus, there is an opportunity for developing countries like India to expand the market share of lubricants. This paper will show the possibility of replacement of mineral oil based lubricants with vegetable oil based lubricants.

## 2. PROPERTIES OF LUBRICATING OIL

Vegetable oils have numerous valuable and useful physico-chemical properties and offer several technical advantages over the mineral oils. Table 1 shows the comparison chart of the properties/specifications of commercial lubricating oil SAE 20W40 and vegetable oils used in this research [5].

**TABLE I: Properties of Lubricating Oil**

Properties Oils ↓	Kinematic Viscosity (at 40°C) cst	Flash point (°C)	Pour point (°C)	Cloud point (°C)	Density (kg/l)
SAE 20W40 oil	134	252	-24	-	0.884
Cottonseed oil	33.5	234	-15.0	1.7	0.9148
Soya bean oil	32.6	254	-12.2	-3.9	0.9138

## 3. EXPERIMENTATION

### 3.1 Sample Preparation

Samples are prepared approximately 20 ml by taking SAE 20W40 oil for both cottonseed oil and soya bean oil with graphite additive in three concentrations. Addition of nano-particles in lubricating oil requires properly weighting of

the nano-particles. So the weight of graphite additive is measured on digital weighing machine with accuracy in milligrams. Dispersion of nano-particles in lubricating oil is also an important parameter of experimentation. So in this research work the magnetic stirrer is used for mixing of nano-particles in oil. Table 2 shows the properties of graphite nano-particles.

**TABLE II : Properties of Graphite Nano Particles**

Nano-particle	Purity (%)	APS (nm)	Density (g/cm ³ )
Graphite	99.9	< 100	2.267

### 3.2 Four Ball Testing machine

DUCOM's four ball tester TR-30 family is designed to evaluate anti-wear (AW), extreme pressure (EP) and shear stability behavior of lubricants. This apparatus measures the coefficient of friction (COF), wear scar diameter and load carrying capacity of lubricating oils under standard operating conditions. So to evaluate the wear preventive characteristics of lubricant we have selected a standard four ball testing machine with standardized testing method i.e. American Society for Testing and Materials (ASTM D 4172). The four ball testing machine uses four balls made of chrome alloy steel AISI standard steel no.E-52100, with diameter of 12.7 mm (0.5 in.). Out of four balls, three at the bottom and one on top which is tighten into the spindle of the test machine. The bottom three balls are assembling in the test oil cup containing the lubricating oil under test. The top ball is rotating at the desired speed while the bottom three balls are pressed against it. The lubricant under test is characterized by evaluating the wear scar diameter formed on the bottom three balls after the test [A. S. Kalhapure et al., 2015]. The Ducom four ball testing machine is as shown in Fig.1.



**Fig. 1. Ducom Four ball Tester**

## 4. RESULTS AND DISCUSSION

The experimental results obtained from anti-wear tests for lubricating oils with and without graphite additive are discussed in this section.

### 4.1 Wear Behaviour

Average values of wear scar diameters for SAE 20W40 oil, cottonseed oil and soya bean oil are listed in Table 3. From this table, it is observed that the wear scar diameters for both vegetable oils are larger than the commercial SAE 20W40 oil. Increase in wear of vegetable oils is because of the continuous removal of metallic soap film. Formation of such film is due to the reaction of the oil with the metallic

surface during sliding. The metallic film is continuously reformed by further chemical reaction.

**TABLE III: Wear Scar Diameters**

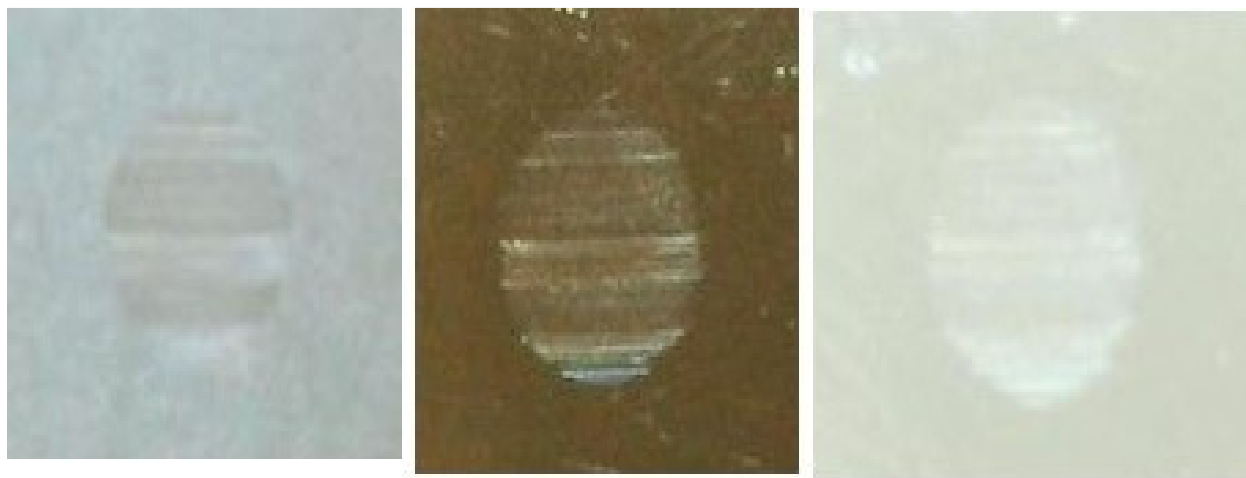
Oil	Wear Scar diameter ( $\mu$ )
SAE 20W40 oil	401.44
Cottonseed oil	653.44
Soya bean oil	674.88

The anti-wear test results for pure vegetable oils i.e. for cottonseed oil and soya bean oil with graphite additive were not found positive. So we have decided to use cottonseed oil and soya bean oil as a blend in SAE 20W40 oil with graphite as an additive. Both cottonseed oil and soya bean oil is added in SAE 20W40 oil with different concentrations as 10%, 30%, 50 % by volume and graphite additive with concentrations as 0.5%, 1%, 2 % by weight. The observations of wear scar diameter for blend of SAE 20W40 oil and cottonseed oil with graphite additive and for blend of SAE 20W40 oil and soya bean oil with graphite additive are listed in Table 4 and 5 respectively.

**TABLE IV: Average Wear Scar for Cotton seed oil Blend with SAE20W40**

Test No.	CSO (% Vol.)	Graphite (% Wt.)	Wear scar diameter (micron)
1	10	0.5	383.77
2	10	1	407.33
3	10	2	420.89
4	30	0.5	450.66
5	30	1	480.33
6	30	2	492.77
7	50	0.5	782.66
8	50	1	803.77
9	50	2	842.44

The wear scar diameters from the table 4 and 5 shows that the anti-wear behavior of blend of SAE 20W40 oil and cottonseed oil with graphite additive and blend of SAE 20W40 oil and soya bean oil with graphite additive is better than the SAE 20W40 oil. It is also cleared that anti-wear ability of cottonseed oil blend in SAE 20W40 oil is better than the soya bean oil blend. Fig. 3 shows the scar diameter for best combination of SAE 20W40 oil + 10% Vol. CSO + 0.5 % Wt. graphite.



**Fig. 2. Scar Images for SAE 20W40 + 10% Vol. CSO + 0.5 % Wt. graphite**

**TABLE V: Average Wear Scar for Soyabean oil Blend with SAE20W40**

Test No.	SBO (% Vol.)	Graphite (% Wt.)	Wear scar diameter (micron)
1	10	0.5	391.66
2	10	1	412.66
3	10	2	429.33
4	30	0.5	462.33
5	30	1	493.66
6	30	2	502.44
7	50	0.5	785.88
8	50	1	809.33
9	50	2	857.11

## 5. CONCLUSION

From experimental results of anti-wear test it is observed that the wear scar diameter for both cottonseed oil and soya bean oil is more than the commercial SAE 20W40 oil. Pure cottonseed oil and soya bean oil with graphite additive doesn't show good anti-wear characteristics than commercial oil. But the combination of SAE 20W40 oil + 10 % vol. cottonseed oil + 0.5 % wt. graphite additive shows lower wear scar diameter than pure SAE 20W40 oil and combination of SAE 20W40 oil + 10% vol. soya bean oil + 0.5% wt. graphite additive. Hence blend of SAE 20W40 oil and cottonseed oil with 0.5 % wt. graphite additive is the best suitable lubricant.

## ACKNOWLEDGMENT

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# Generation IV Nuclear Reactors: Sodium Fast Cooled Reactor

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**Abstract:** The aim of this paper is to introduce the latest innovation in the field of nuclear energy extraction. As compared to the past technology in this field, recent innovations have resulted in increase in efficient as well as safe energy extraction. The latest upfront proposal in this field is the Generation IV reactors. These are the type of reactors which are currently being the most effective solution for most of the drawbacks in nuclear energy extraction. The Generation IV International forum which is a co-operative international endeavor carries out various R&D in the favor of Generation IV nuclear reactors. This paper focuses on a type of Generation IV reactor which is Sodium Fast Cooled Reactor. This reactor uses metallic liquid as its working fluid, thus considered as beneficial in various aspects. Thermodynamically analyzing this system, it results in overall improvement in plant's performance as well as the safety measured required to be taken care of in case of previous reactor designs.

**Keywords:** Nuclear Fission, Generation IV Reactors, Sodium Fast Cooled Reactor (S.F.R.), Fast Neutron Technology

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## 1. INTRODUCTION

Energy is the toll which is responsible for almost everything happening in our universe. As a matter of fact, limiting our discussion for the sake of humanity, human beings by the time have found out many sources of energy which includes various renewable and non-renewable sources. The most prominent form of energy demanded by the humans is the 'Electrical'. This electrical form of energy, rather 'Electricity' is extracted from various resources like solar panels, burning fossil fuels to run thermal power stations, hydro power stations, nuclear power plants and many more. Out of all, nuclear energy extraction to generate electricity is one of the most underestimated power source. This source if used efficiently, could single handedly suffice the global energy needs. But due various limitation and drawbacks, this technology is not so widespread.

Nuclear energy extraction is mostly based on the principle of 'Nuclear fission'. In this process a heavy isotopic atom (mostly Uranium  $^{235}_{92}\text{U}$ ) is bombarded by neutrons which results in stabilizing the atomic nucleus. This process degrades the atom to two daughter atoms along with tremendous energy release. These nuclear processes are governed by various quantum mechanics laws, out of which the 'Einstein's Equation ( $E = mc^2$ )' indicates the tremendous amount of energy release is due to mass to energy conversion. This is because the absolute mass of the atom going under fission is quite large as compared to the total mass of the fission products.

The place where these reactions are carried out are called as 'Nuclear Reactors' which are located in 'Nuclear Power

Plants'. Elaborating the context, the nuclear reactor is a confined shell where splitting of atoms occur and a working fluid is then used to extract the thermal energy produced inside, rest conversion is similar to that of a conventional thermal power plant. The reactor plays a crucial role in energy extraction as it confines the radioactive materials from the environment and supports the nuclear fission energy extraction. But due to lack of modern techniques and analysis techniques, this reactors were not capable of supporting maximum energy extraction previously. To overcome this drawback, 'Generation IV' reactor were introduced, which are briefly elaborated in the further paper. The paper focuses on 'Sodium Fast Cooled Reactor' which is a type of Generation IV reactor.

The rest of this paper is organized as follows. Section 2 briefly reviews the basic principle or the idea behind S.F.R. Section 3 presents the analyzed results of the use of fast neutrons. The effect due to the use of liquid sodium is elaborated in Section 4. Furthermore, discussion about improved safety and drawbacks is in section 5. Finally, conclusions are presented in Section 6.

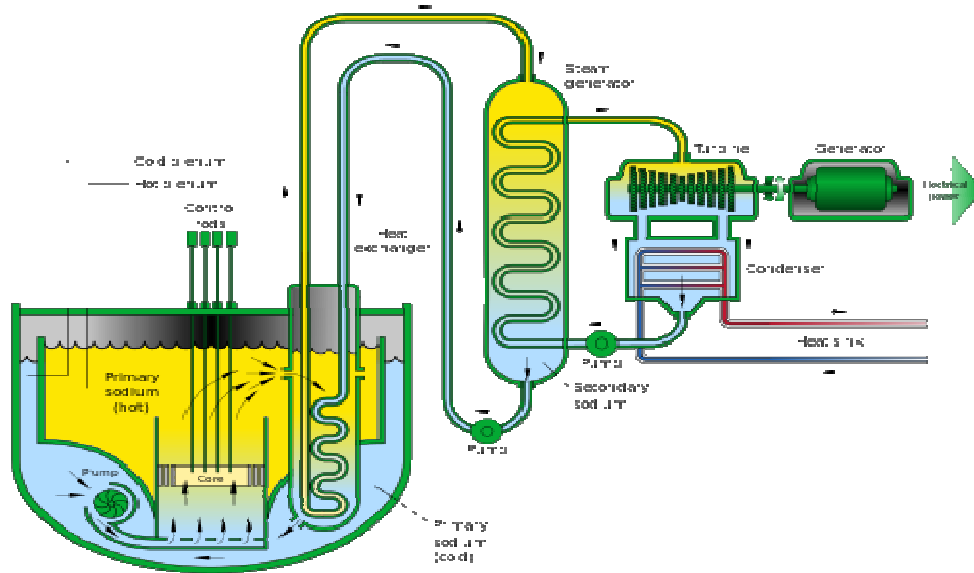
## 2. THE GENERAL IDEA OF SODIUM COOLED FAST REACTORS

Conventional reactors include Pressurized Water Reactor (P.W.R.) or Light Water Reactor (L.W.R.) which use water as working substance as well as for the purpose of coolant. In these cases the water used is heavy, thus it acts as a moderator minimizing the velocity i.e. energy of the fast neutrons, making them thermal neutrons. Also the water has to be kept under high pressure to raise its boiling point, also

the use of water limits the operating temperature range of the reactor.

To overcome such drawbacks, Sodium Fast Cooled Reactors are designed. It includes use sodium as a coolant which is actually in contact with the reactor core fuel and causes required heat transfer. The generalized concept of

S.F.R. is as shown in the figure. The reactor core fuel is dipped in the sodium liquid (primary) which absorbs the heat generated during the fission. This primary sodium is not directed out of confined space, as it might spread the radiation. Thus a secondary sodium loop is used for intermediate heat transfer between core and the steam generator.

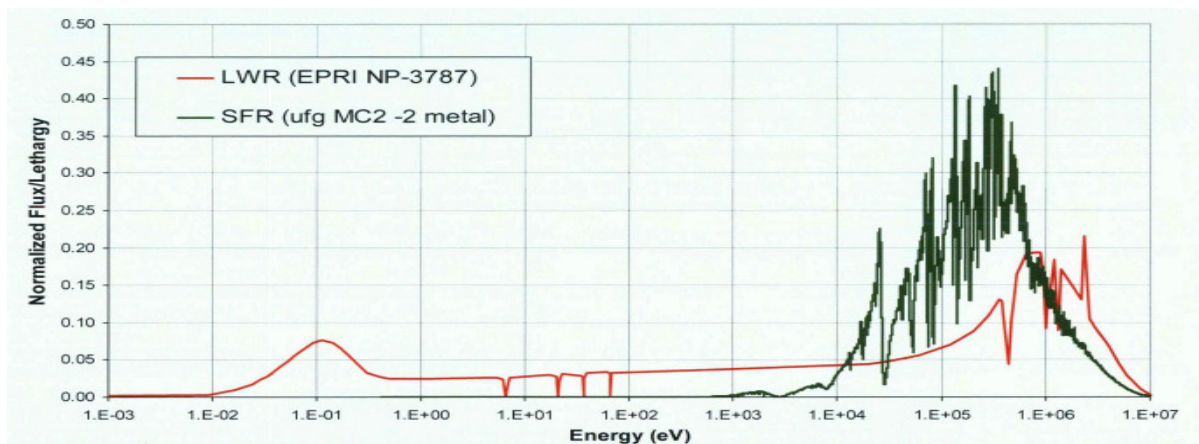


**Fig. 1. Sodium Fast Cooled Reactor Basic Design**

The further loops are same as that of the conventional steam generator power plants. The pumps used are mostly electrostatic. As the fission starts, the primary sodium begins to boil, this boiled sodium is circulated to a heat exchanger which exchanges heat between the secondary sodium containment. This heat is finally given to a steam generator which drives the turbine in order to generate the electricity.

There are few designs which eliminate the use of steam generators and the vaporized secondary sodium is allowed to flow on turbine. But in this case, the turbines are to be specially designed. Also there are many problems when the sodium accidentally begin to solidify in the condenser. Thus the prior design is mostly recommended for the application.

### 3. THE IMPACT OF FAST NEUTRONS ON THE FISSION



**Fig. 2. Normalized Flux as the function of the neutron energy**

The graph above shows the relation between Normalized Flux and Energy of a neutron in two types of reactor which are Light Water Reactor (L.W.R.) and Sodium Cooled Fast Reactor (S.F.R.). From the graph, we could clearly analyze and conclude the following terms:

### 3.1 REDUCTION IN RADIOTOXICITY OF FISSION WASTE

Fast neutrons cause reduction in total radio toxicity of the waste and thus dramatically reduces the radioactivity of the fission by products. This is due to the large ratio between splitting and neutron capture due to which any minor actinide like plutonium can be much easily fissioned as compared to slower neutrons.

### 3.2 BREEDING OF ALMOST EVERY ACTINIDE

The problem of 'Fuel Shortage' is considerably eliminated against Uranium fueled reactors. As they allow almost

every actinide to be breed in the reactor, thus fuel shortage is not the problem.

### 3.3 SURPLUS AMOUNT OF NEUTRONS

Larger surplus neutrons beyond the need of those required to sustain chain reaction are produced. These neutrons can be used to produce extra fuel or to transmute long half-life waste into less troublesome isotopes. Thus this technology enables us to produce abundant of neutrons which breed more fuel than they consume.

### 3.4 TRANSMUTATION OF INCONVENIENT TRANSURANIC ELEMENTS

It Trans mutates the inconvenient even numbered transuranic elements. It transmutes them then fissions them producing power, thus making these former wastes valuable.

### 3.5 ANALYSIS OF ABOVE STATED POINTS

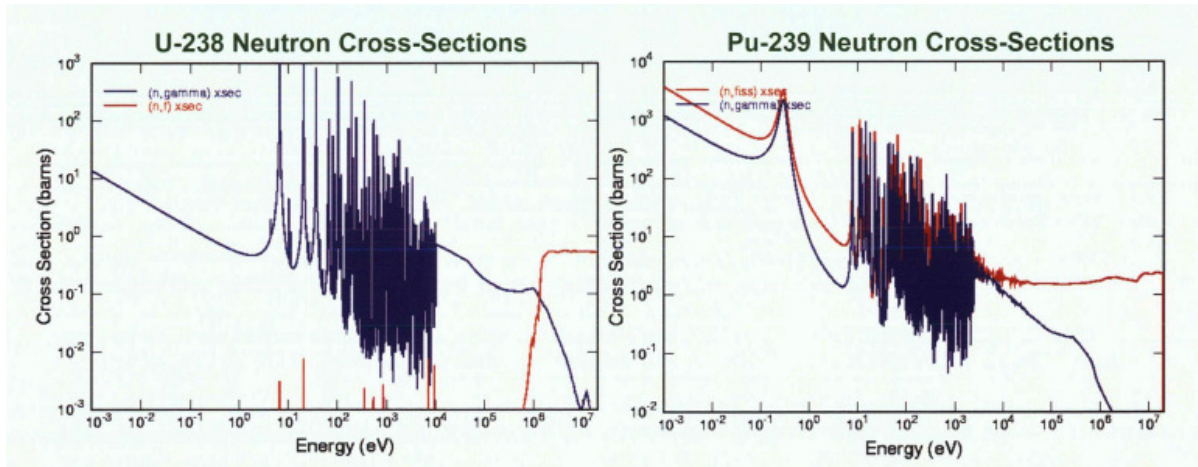


Fig. 3. Effect of Neutron Energy on Transmutation

As from the graph it can be understood that as the neutron energy increases the capture cross section increases which causes higher fission/capture ratio. This is because the capture cross sectional area depends strongly on the speed of the incoming particle, thus the reaction rate can be given as the integration over whole range of energy:

$$R = \int_E N \varphi(E) \sigma(E) dE$$

At a particular range of neutron energy, it is observed that cross section increases at an undetermined stage. This is due to the resonance of the atomic nuclei at resonant nuclear energy. This causes increased fission rate, and the other results are explained above.

## 4. EFFECT OF LIQUID SODIUM COMPARED TO CONVENTIONAL WORKING FLUID

As the Sodium liquid is used as the working medium in this reactors, it has its own set of advantages associated with it. Due to some exclusive properties of this working substance following are some advantages observed.

### 4.1 EXCELLENT HEAT TRANSFER RATE

Sodium being used as a liquid metal, the heat transfer rate is greatly increased. For liquid sodium, the thermal conductivity is quite higher than the thermal conductivity of water. This allows greater amount of thermal energy to be transferred between the reactor and the steam generating

unit. The overall result is improved thermal efficiency of the plant

#### **4.2 LESS NEUTRON CAPTURE CROSS SECTIONAL AREA**

Sodium has very less neutron capture area. This causes less obstruction to the neutron flow i.e. sodium does not moderates the flow of neutrons sustaining the fast nature of the neutrons. This also means very slight amount of sodium would be exposed to the neutron flow, hence less sodium gets radio activated.

#### **4.3 HIGHER TEMPRATURE RANGE OPRATION**

As sodium melts at 371K and vaporizes at 1156K allowing a total temperature range of 785K. The large temperature gradient indicates the large heat reserved within the sodium. This allows greater extraction of the energy from the core as compared to conventional coolants increasing thermal efficiency.

#### **4.4 OPERATES AT LOW PRESSURES**

Liquid sodium can be pumped at lower pressures by still maintaining the effectiveness of energy extraction rate. Here the sole purpose of the pumping is to circulate the flow of liquid sodium and not to increase its pressure. This minimizes the pumping expenditure, resulting in increase in overall plant efficiency.

#### **4.5 USE OF ELECTROMAGNETIC PUMPS**

Electromagnetic pumps can be used to circulate the liquid sodium than the conventional pump designs. This minimizes the amount of moving parts, reducing the losses to some extent. The electromagnetic pumps can be made electrostatic, which further minimizes the electric interaction with the core reactions.

### **5. SAFETY FEATURES AND DRAWBACKS**

The plant safety features are some other systems which can be used in conjunction with many other reactors. However S.F.R. has some few of its inherent characteristic features for safety. If somehow the fission becomes uncontrolled, the liquid sodium is capable to absorbing the excess amount of heat produced in the reactor core. Also it prevents the overheating of the reactor core do to the large heat absorbing property. As the sodium has less neutron capture cross section, less free neutrons are suspended into the

sodium flow. If somehow the pumping system fails, the natural heat decay could significantly cool the system. Mostly any type of actinide fuel is used, thus the fuel rods can be designed in a fail safe way.

The most adverse drawback of this system is the reactivity of sodium with the air, concrete material and conventional piping material. This forces us to find an alternative for the replacement of conventional materials. The sodium also gets significantly radio activated by forming its isotope ( $^{24}\text{Na}$ ) which usually degrades in 3 to 4 days if reactions are halted. Liquid sodium can't be used directly to power the turbines, thus steam generators are required to be employed.

### **6. CONCLUSION**

S.F.R. promises a better future for the nuclear energy extraction due to its exclusive characteristics and design advantages. Though there are many Generation IV reactor design proposed around the world, the design of S.F.R. predominates the feasibility among all. It also reduces the fuel consumption rate by actually increasing the effectiveness of the nuclear fission rate. It also takes care of the transuranic remains of the reaction by disintegrating them.

It could be finally concluded that despite of few drawbacks the S.F.R. provides a better energy extraction technique in the field of nuclear energy. These drawbacks by the time can be eliminated or minimized by the use of undiscovered techniques. Thus S.F.R. provides a better option of replacement for currently running nuclear reactors.

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# Gear Churning: A Review

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**Abstract:** Gear drives are extensively used for speed optimization and power transmission in Industrial equipments in steel, cement, power, plants, windmills, automobiles, mining etc. These drives are generally lubricated using a large sump of oil, therefore a significant amount of energy is consumed not only in overcoming the metallic friction, but also in pumping, agitation and overcoming the viscous drag (churning losses) experienced in the contact zone. This viscous drag or churning is primarily dependent on viscosity as well as base oil types, oil level and its properties. This paper reviews information on churning power loss based on experimental investigations, empirical methods and Simulation with Computational Fluid Dynamics (CFD). The aim of the review is to provide a comprehensive compilation of published information on churning power loss to assist gearbox designers in identifying relevant experimental and modelling information. While it is clear from the review of published work that the rotational speed, gear geometrical parameters, lubricant properties, depth of immersion are important parameters for churning loss. Other thing noticed that major power losses work is carried out on parallel axis gear only.

**Keywords:** Gear, churning loss, Power loss

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## 1. INTRODUCTION

Gears have been known for centuries as the most efficient medium of transmitting loads. However, due to the environmental awareness and more stringent legislation in the market place, the demands on more efficient gearboxes has increased to comply with the needs. Due to increase in energy costs as well environmental concerns, the focus has shifted towards improving efficiency of a gearbox by analyzing factors which directly impact efficiency of a gearbox.[ R. Meshram, 2012] Literature reports that a major portion of energy is lost in the gearbox itself. Intensive research has been carried out lately in this area in order to understand the sources of losses and factors that contribute to the power losses in the gearboxes.

Losses in gearbox can be divided into load dependent losses and non-load dependent losses. Load dependent losses consist of gear friction loss and bearing friction loss. On the other hand, non-load dependent losses consist of oil seal loss, gear churning and windage loss and bearing churning and windage loss. A considerable amount of research has been carried out in order to correlate gearbox parameters including the lubricant properties to the non-load dependent losses. A number of equations showing the relationship between the gearbox parameters and the losses have also been published. Most of the equations are either empirical or semi empirical derived through extensive series of experiments. However, due to the complicated geometries and other parameters in the gearbox, the reliability of the equations are still been discussed. Many researchers believe that intensive research is still needed in this area in order to validate the existing equations or explore other parameters that might influence the losses in the gearbox.

Churning loss can be defined as the losses due to the actions of gears moving inside the lubricant and losses due to entrapment of lubricant in the gear mesh. [ R. J. Boness, 1989] The churning losses are associated to the rotational movement of the mechanical. Lubricant churning is one of the more common factors that affects both bearings and gears. It occurs when the bearing or gear must churn through the lubricant as it performs its regular task. The majority of these machines are splash-lubricated, which means they must operate at the proper lubricant level to be able to lift and splash lubricant to all surfaces inside the machine. This is where lubricant churning can become an issue. If the lubricant level is too high, either because too much oil has been added or the bearings have been overgreased, the machine must work harder to push through the added lubricant. This is the basis of that churning condition. The same thing happens to a machine when the lubricant level is too high. It works much harder to push through the added lubricant, which results in higher operating temperatures, decreased efficiency and a reduction in the life of both the lubricant and the machine. Besides the lubricant level, another variable is the lubricant being used. If the viscosity is too thin, then excess friction due to metal-on-metal friction is generated, causing machine wear and premature failure. If the viscosity is too thick, this leads to viscous drag, which causes very similar issues as having a lubricant level that is too high.

D. P. Townsend, 1985, defined churning losses as the action of the gears moving the lubricant inside the gear case and referred in particular to the losses due to entrapment of the lubricant in the gear mesh. Windage and churning losses are present as a result of oil/air drag on the face and sides of

the gears as well as in the meshing zone[ G. M. P. Europe]. [S. Seetharaman, 2009] claim that the churning losses is mainly divided into two parts: 1) When the gear is rotated, the power losses were caused by the movement of the lubricating oil stuck on the gear (This part includes three aspects: power losses were generated by interaction of the periphery of gear and lubricating oil; power losses were generated by interaction of the face of gear and lubricating oil; Scroll power losses were generated by lubricating oil in gear cavity); 2) When the gear is meshed, the gap between the two gears is changed and makes the oil being sucked and extruded which cause power losses. Yasutsune et al [6] conducted a research by using a flash frequency detector which aims to analyze and discuss the characteristics of churning losses.

If there is no torque applied, friction between gear teeth is very small not affecting the overall power loss. No Load Power Loss depends mostly on Gearbox rotational speed, Lubricant oil viscosity at the operating temperature, Lubricant oil volume, Gearbox geometry and internal parts arrangement, Environment temperature in the surroundings influences the heat evacuation [ D. Cetrib, 2010]

As per ref [ J. Kuria and Kihui, 2011] It can be observed that the windage and churning losses increase with an increase in the rotating speed and the diameter of the gear. However, these losses are not significant for speeds below 1000 rpm. Taking a critical view of existing methodologies, Bones, 1989 carried out churning torque measurements for discs of varying geometries at different immersion depths using three different fluids. Using a combination of von Karman's equations and a Reynolds number based on the disc chord length as the characteristic length, he proposed a methodology to calculate churning losses in gears in three different regimes: laminar transition and turbulent. Terekhov, 1975 proposed a similar methodology for single and meshing gears based on gear experiments under highly viscous lubricant conditions and low rotational speeds. Both Bones and Terekhov, 1975 expressed churning loss in terms of a dimensionless churning torque. Luke and Olver, 1999, performed a number of experiments to determine churning loss in single and meshed spur gear pairs. They compared their experimental observations on spin power losses with the empirical formulations of Bones, 1989 and Terekhov, 1975 and found that contrary to what Bones had predicted, the spin power losses were not strongly affected by the viscosity of the lubricant. Furthermore, their observations called into question the attempt used to characterize spin power loss based on a Reynolds number dependent on lubricant viscosity. Changenet, 2007 also reported a minor reduction in gear churning losses with lower lubricant viscosity. In a dip-lubricated gearbox, Changenet and Velex, 2008 showed that gear churning losses are affected by the gearbox housing dimensions. The gear geometry also affects gear churning losses: larger face widths give bigger

churning losses. The gear module does not seem to influence no-load losses significantly, although it is related to gear mesh losses, which affect efficiency. In the ref [ C. N. Eastwick and G. Johnson, 2008] churning loss of spur gear system with jet lubrication is measured and several analyses are proposed. A lubricant plays an important role in overcoming these power losses.[ T. Jan, 2011; M. Hochmann, 2011; V. Fontanar, 2016] A carefully formulated lubricant with friction modifiers helps in reducing frictional and churning losses in mixed, elastohydrodynamic and boundary lubrication regime.[ R. Meshram, 2012]

Different approaches are available to calculate the churning losses in transmission systems. These are:[ B. R. Höhn and K. Michaelis, 2004]

- Experimental Investigations of Gear churning
- Calculation with empirical equations
- Simulation with Computational Fluid Dynamics (CFD)

## 2. EXPERIMENTAL INVESTIGATION OF GEAR CHURNING

Most of experimental studies considered a single gear, disk, or bladed rotor immersed in oil.[ T. T. Petry, 2008] These oil churning studies were also devoted to developing empirical equations to obtain a dimensionless churning moment coefficient. A common way to lubricate vehicle gearboxes is dip lubrication. The gears are partially immersed in the oil sump at the bottom of the gearbox housing, and as they rotate during operation they lubricate the whole gearbox by dragging and splashing the lubricant around, including into the gear mesh. Dragging in the lubricant is called churning. When using dip lubrication, energy losses that arise due to the dragging of the gears in the lubricant are called gear churning losses. Changenet and Velex, 2007; Changenet and Velex, 2008 investigated the windage and churning losses of spur gears. According to his findings, the tip diameter and the gear width have the biggest influence on both losses. Andersson and M. Andersson, 2014 Höhn et. al, 2008 showed that gear speed has the largest effect on gear churning losses. Losses increase with increasing immersion depth. The strong link between high power losses and increasing rotational speed and immersion depth of the gears was also reported by Seetharaman, 2009.

- 1) Spur Gear. (P. Luke, 1999; T. T. Petry, 2008; R. Martins, 2010; L. S. Akin, 1975; A. Kahrama, 2016; A. Kahraman, 2015; F. Chaari, 2012) all investigated churning due to spur gear in isolation. Changenet and Velex, 2007 developed test rig for spur gear churning loss measurement and also reported a minor reduction in gear churning losses with lower lubricant viscosity. In a dip-lubricated gearbox,

Changenet and Vex, 2008 showed that gear churning losses are affected by the gearbox housing dimensions. The gear geometry also affects gear churning losses: larger face widths give bigger churning losses. P. Luke [10] conducted experiment on simple two shaft spur gear test rig. The gear were straddle mounted on tubular shaft with internal miniature ball bearing (20 mm outside diameter) to minimize the frictional bearing torque. Churning losses were measured by direct determination of torque using strain gauge. And they compared their experimental observations on spin power losses with the empirical formulations of Bones, 1989 and Terekhov, 1975 and found that contrary to what Bones had predicted, the spin power losses were not strongly affected by the viscosity of the lubricant. Furthermore, their observations called into question the attempt used to characterize spin power loss based on a Reynolds number dependent on lubricant viscosity.

- 2) Other gear: All of the tests were carried out on spur gears, until a helical gear efficiency test machine was developed to enhance the testing capability to include helical gears. Dawson', 2006 experiments by adding several helical gear measurements. With larger helix angles, the power losses are lower as the gear teeth slice through the lubricant rather than displacing the lubricant along the whole gear face width. [ P. J. Smith ]. A very few author has mentioned or worked on churning loss of other gear except spur gear.

### 3. CALCULATION WITH IMPERICAL EQUATION

Terekhov, 1975 and Boness, 1989 were one of the first to investigate the churning losses in dip-lubricated geared transmissions for a wide range of operating conditions. They introduced several empirical equations based on different Reynolds and Froude numbers. The findings show that the tip diameter, the gear width, the immersion depth, the angular velocity, the volume of oil and the density are the main influence factors on the churning loss of gears.

#### 3.1 Von Karman's Fluid Flow

The fundamental aspects of the research of churning losses have a relation with the fluid mechanics of an axially symmetric, smooth-walled, right-circular rotating plane disc. The steady flow generated by a plane disk of large diameter rotating with a uniform angular velocity in contact with an incompressible viscous fluid was first investigated by Von Karman (1921), who used the form of momentum analysis for turbulent flow as a solution.

$$C_m = \frac{2Mt}{0.5\rho\omega^2 R p^2 A} \quad (i)$$

#### 3.2 Bones, 1989 Experimental Formula

The formula of churning torque proposed by Boness (1989), who investigated the drag torque generated by discs of varying geometry and gears rotating up to 3000 rev/min at different immersion depths in water, 15W40 oil or SAE 10W is expressed in terms of a dimensionless torque coefficient as  $C_m$ .

$$C_m = \frac{Mf}{0.5\rho\omega^2 R p^2 A} \quad (ii)$$

#### 3.3 Terekhov's, 1975 Experimental Formula

Terekhov conducted a number of experiments on rotating single and meshing spur gears with high viscosity lubricant and low rotational speed. The calculation of the torque coefficient,  $C_m$  is deduced from dimensional analysis based on the flow regime and the rotating direction of a pair of gears. If gears rotate so as to approach one another in the oil bath, churning torque  $C_{ch}$ .

$$C_{ch} = \rho \left( \frac{\pi N s}{30} \right)^2 R_o^4 b C_m \quad (iii)$$

$$C_m = \psi_1 \left( \frac{h}{R_o} \right)^{\psi_2} \left( \frac{h}{V_m} \right)^{\psi_3} \left( \frac{v_g}{V_m} \right)^{\psi_4} \left( \frac{b}{R_o} \right)^{\psi_5} Re^{\psi_7} Fr^{\psi_6} \quad (iv)$$

#### 3.4 Changenet's, 2007 Experimental Formula

In order to isolate the contribution of churning, Changenet and Vex (2007) measured the losses with lubricant and without lubricant. For high-speed conditions, windage losses were measured in the absence of lubricant and were subtracted from the total losses. The values of churning losses were obtained by using thermocouples to measure the ambient and the lubricant temperatures after thermal equilibrium between the two.

$$C_{ch} = 0.5\rho \left( \frac{\pi N s}{30} \right)^2 S_m R_p^3 b C_m \quad (v)$$

$$C_m = \psi \left( \frac{h}{D_p} \right)^{\psi_2} \left( \frac{h}{D_p^{\psi_4}} \right)^{\psi_3} \left( \frac{h}{D_p} \right)^{\psi_5} Fr^{\psi_6} Re^{\psi_7} \quad (vi)$$

#### 3.5 Höhn's, 2004 Experimental Formula

Höhn et al. took into consideration the mean oil temperature of lubricant from a thermal balance between the generated heat in a gearbox and that dissipated from the gear case surface for a pinion meshed with a gear under splash lubrication. This approach is represented in following gear

$$C_{ch} = C_{sp} C_a e^{cb} (V_t/V_{to}) \quad (vii)$$



#### 4. SIMULATION WITH COMPUTATIONAL FLUID DYNAMICS (CFD)

CFD (Computational Fluid Dynamics) methods offer a very flexible way to investigate the oil distribution and the churning power losses, with almost no restrictions on the housing shape and operating conditions. In the first step, CFD models are prepared to estimate the splash loss for single gear wheel and validated against the measurement data. In the second step, a CFD model is created to estimate the splash losses for a gear pair which includes intermeshing power loss due to oil squeezing between the gear teeth, as validated by the published data. In the third step, a parametric study is done for a gear pair to find out the percentage of intermeshing losses for different operating conditions such as rotational speed, temperature and oil level. Finally, in the fourth step, a CFD method is proposed to estimate the splash losses for the complete Manual Transmission (MT) gear box. Considering the static condition of gear box, splash loss is estimated for the gears dipped in the oil. To estimate the splash loss of gear pair, the individual contributions of each gear are then summed up and the percentage of intermeshing losses are added to the sum value. Some work on the hydraulic losses was presented by Dowson, 2006 regarding the windage losses or by F. Concl., 2013 and by Seetharaman et al., 2009 who have concentrated on the churning power losses. B. R. Höhn, 2004 built up CFD model and used to investigate the oil distribution and the churning losses inside a single-stage gearbox of the FZG back-to-back efficiency gear test rig. Their investigations showed that the finite volume CFD method is a valid tool for predicting the churning loss and oil distribution inside a gearbox. In another paper, C. Gorla, 2012 The simulations were performed for two different components, disk and gear. The power losses of the dip lubricated disk appear significantly lower than the power losses of dip lubricated gear. The results of the experiments confirmed that the CFD represent a valid method to predict power losses. The error in the predictions for the analyzed cases was lower than 5%.

#### 5. CONCLUSION

This review describes a number of studies that have investigated gear churning. While it is clear from all of these investigations that the rotational speed, gear geometrical parameters, lubricant properties, oil sump level and temperature of the fluid surrounding the gear are important. The majority of the modeling methodologies are experimental correlations derived from specific experiments that have unique elements, making a general conclusion regarding the best methodology difficult. It is clear from this review that a modeling methodology capable of being used for all gear types and configurations is required, which allows analysis of the fluid dynamics phenomena.

#### 6. NOMENCLATURE

Mf=Fluid friction drag torque [N m]	Ro=Outer radius[m]
$\rho$ = Fluid density [kg/m ³ ]	B=Width of a gear[m]
A = Wetted surface area [m ² ]	H= Immersion depth of gear into oil
$\Omega$ =Angular velocity [rad/sec]	V1= Immersed volume of the gear
Rp=Pitch radius of gear or disc[m]	Vg=Total immersed volume
K and $\gamma$ = Experimental constants	Fr=Froude number
Ns=Number of revolutions per minute	Cm=Dimensionless churning torque

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# Productivity Improvement at Coke Plant - A Case Study

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**Abstract:** This paper aims to address the problem faced in a large steel industry in a developing country like India about contract labor productivity management. According to National Steel Policy 2017, India steel has an output multiplier effect of nearly 1.4X on GDP and employment multiplier factor of 6.8X & in employment multiplier the most of it is associated with contract manpower. This topic has been selected with a view to estimate the role of manpower (contract labours) in achieving organization's objectives. Organizations will be able to recognize the reasons behind poor performance of contract labours and can adopt measures to improve them. Thus organizations can achieve its goal by satisfying various needs of labours. In this paper a detailed study has been conducted in coke plant with using work sampling method & this study would help in improving the contract manpower productivity in coke plant.

## 1. INTRODUCTION

Indian steel consumption is forecast to grow by about 5% - 6% and Indian crude steel capacity is also expected to rise from 122 million tonnes (MT) in 2015 to about 300MT in 2030 (NATIONAL STEEL POLICY 2017). India became the 3rd largest producer of steel in 2015 and is now well on track to emerge as the 2nd largest producer after China. There is significant potential for growth given the low per capita steel consumption of 61 Kg in India, as compared to world average of 208 Kg. Indian economy is rapidly growing with enormous focus on infrastructure and construction sector. Several initiatives mainly, affordable housing, expansion of railway networks, development of domestic shipbuilding industry, opening up of defence sector for private participation, and the anticipated growth in the automobile sector, will create significant demand for steel in the country. To produce steel, raw materials such as Iron Ore, Coal Fines, Lime, etc. are required (NATIONAL STEEL POLICY 2017). It has observed that to produce 1MT of steel, it requires around 3 MT of raw material.

In Iron making process, coal is one of the major raw materials. In coke oven, coal is carbonized to coke. Coke oven batteries are much cost intensive and vital supporting system in integrated steel plant, All over the world there is increase in endeavor to prolong the life of Coke plants, particularly the batteries in order to reduce investment cost to guarantee Coke supply to blast furnaces. In India generally the battery life is 20-25 years, but regularly repair/maintenance can prolong the life of the coke oven batteries up to 35-40 years.

This paper covers various work procedure & instructions which are carried out by contract labours in a coke oven battery for enhancement of Battery life and this report also shows the productivity of contract labours at coke plant.

## 2. PROCESSING MAPPING & SCOPE

In this study the mapping of the existing contract jobs has been done in coke plant. Detailed study with Ration delay method is done to know the engagement level of the contract labours in coke plant. In Coke Plant 22 vendors & 1078 contract workers are engaged to perform different job in coke plant. The jobs performed in the coke plants are oven doors repairing, ceramics welding, cleaning of SCP machine, Door Extractor, Quenching Loco, CGC car in operation, Spillage circuit cleaning of SCP yard & loco Yard, oven top cleaning AP water seal through cleaning or other jobs. The detailed activity chart is developed from the work permit signed by the supervisor.

In this project we restrict our study to only 4 major service providers in coke plant. This 4 service providers carry out the most of the contract work in coke plant.

**TABLE 1: Vendor Name & Gate passes number engaged in Coke plant**

SL NO	VENDOR NAME	No of Permanent Gate Passes	No of Temporary Gate Passes
1	B N DUTTA	143	59
2	FOSBEL INDIA PRIVATE LIMITED	25	0
3	UNITED AIR EXPRESS(UAE)	237	0
4	SHIVAM ENGG ENTERPRISES	161	0
Total Number		566	59

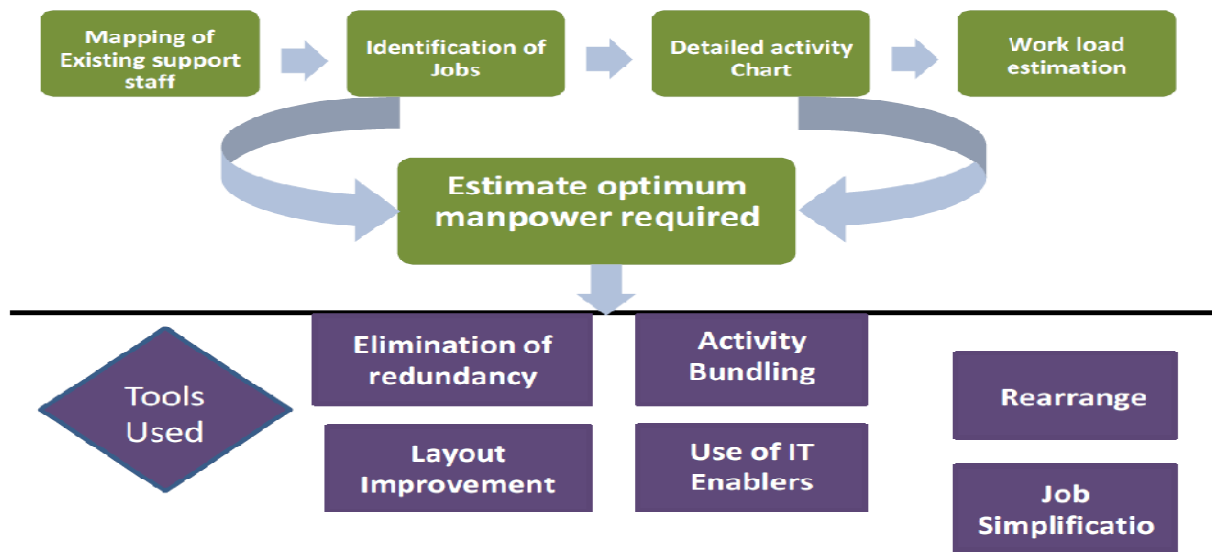


Fig. 1. Block diagram of approach adopted in study

### 3. APPROACH ADOPTED

The field studies of contract personal have been conducted by Work Sampling technique & Ratio Delay Method by noting down the activities of workers at an interval of every 2 or 5 minutes. The study have conducted in General Shift

(8 AM – 5 PM) to find out the time when labours are engaged in productivity work (Performing the required Job, cleaning & forced delay) & Non productivity work ( Idle, Tea break, late start early finish avoidable delay). In each a group of 4-9 contractor workers are engaged with 1 supervisor to supervise the job safely.

TABLE 2: Study Sample format is shown below

FIELD STUDY OF CONTRACT LABOUR(B N DUTTA) FOR BATTERY 5,6 & 7(COKE PLANT)					
LOCATION	BATTERY 5,6,7 (COKE PLANT);7A 109				
JOB	OVEN DOOR REPAIRING(MECHANICAL WORK)				
DATE	19/9/2016				
	LABOUR-5,SUPERVISOR-1				
SL NO	DESCRIPTION	L1	L2	L3	L4
	PRODUCTIVE WORK	IN min			
1	Performing mechanical work	190	185	125	90
2	Cleaning the work area	25	10	25	10
3	forced Delay	45	45	45	45
	SUB TOTAL	260	240	195	145
	NON PRODUCTIVE WORK				
1	Standing Idle/Sitting Idle/Relaxing on Site	10	15	40	15
2	Drinking Water/Washroom	5	5	15	5
3	Early Finish	60	65	70	150
4	Late Start	115	125	130	135
5	Avoidable Delay	0	0	0	0
6	Tea Break	30	30	30	30
	SUB TOTAL	220	240	285	335
	TOTAL	480	480	480	480
	UTILIZATION	54.17%	50.00%	40.63%	30.21%
	AVERAGE UTILIZATION	43.75%			

#### 4. OBSERVATION & ANALYSIS

In study it was found out that the number of contractor engaged for the job are more than the required number as the supervisor who sign the work permit never check the work content result in low percentage of utilization. The supervision of contract jobs is low resulting in late start &

early finish of work & improper break time (Long breakfast & lunch time) of contract labours. In Coke Plant the transport of coal & coke is done through conveyor. Due to some wear & tear in conveyor belt there is spillage of coal & coke resulting in increase in number of contractor workers engaged in the cleaning activity.

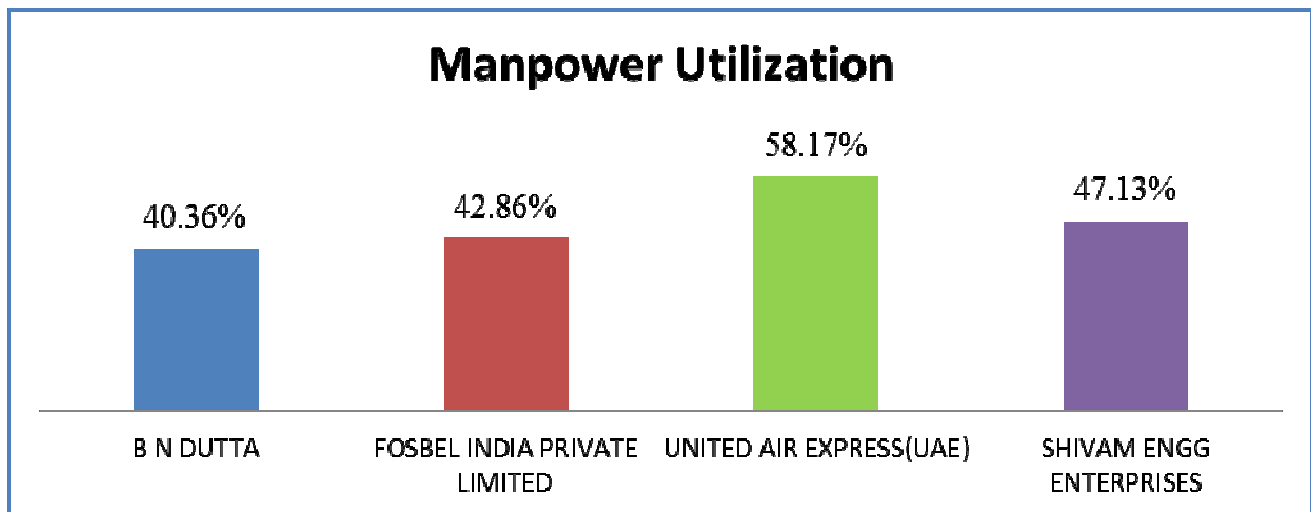


Fig. 2. Utilization of Contract Manpower based on study

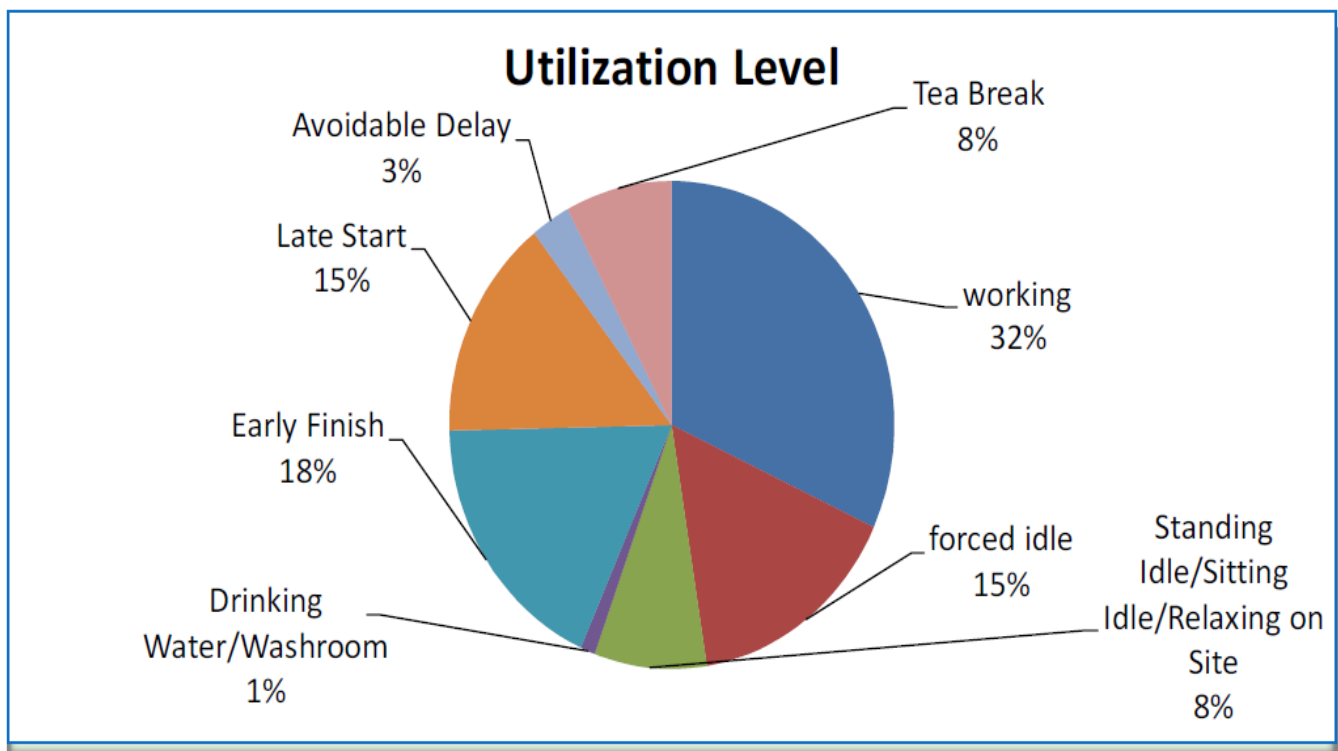


Fig. 3. Contract Manpower works distribution

## 5. RECOMMENDATIONS

The analysis indicated that the utilization of the contract worker is low in coke plant resulting in decrease in productivity of contract labours in coke plant. To enhance the contract labours productivity & engagement following suggestions are made to the Coke plant management.

- 1) Before assigning any job Shift foremen should visit the worksite to get hold of the work content & accordingly assigned the contract manpower to perform the job.
- 2) The officer responsible for the concerned area should record the foremen & assistant foremen - visits to the workplace.
- 3) Proper maintenance of the coal conveyor circuit should be done to reduce the spillage in the coke plant.
- 4) Foremen working in A shift should generate the work permit instead of general shift foremen as this will reduced the delay in start time of the contract work.
- 5) Breakfast, lunch Time should match with the contractor labours break time this will result in decrease in improper break time of contractor labours.

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# Performance Optimization During Transient Operation for Turbocharged DI Diesel Engine

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**Abstract:** The most attractive feature of compression ignition (diesel) engine is its excellent, fuel efficiency, low sensitivity in terms of air-fuel ratio variations, high torque and high tolerability in peak cylinder pressures and temperatures. However, they emit higher amount of visible exhaust termed as smoke and this smoke is very much high during transient operation, especially in turbocharged diesel engine. Hence control of transient emissions from turbocharged diesel engine is an important objective. Starting in particular, is process of significant importance owing to its major contribution to the overall emissions during transient test cycle. A present paper includes study of peculiar smoke behavior during steady state and transient operation of turbocharged diesel engine. A methodology was established for carrying out transient simulation using one-dimensional modeling. Experimental study was carried out to collect engine performance and emission related data. As turbocharger lag one of the predominant parameter in transient emission, this paper made emphasis on effect of various turbocharger design parameters like type and size of housing of turbine and compressor side, speed, material of turbine and compressor which helps in reducing turbocharger lag. Simulation results showed that reduction in smoke emission can be achieved by increasing compressor speed, reducing turbine housing, increasing air flow and which was further validated by experimental results.

**Keywords:** Turbocharged diesel engine, Smoke, Simulation, Transient conditions

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## 1. INTRODUCTION

The turbocharged compression ignition (diesel) engine is nowadays the most preferred prime mover in all types of applications owing to its reliability that is combined with excellent fuel efficiency. Direct injection diesel engines, due to lack of throttling losses, exhibit low brake specific consumption and thus low carbon dioxide (CO₂) emissions especially at part loads. Further, due to their ability to operate at low equivalence ratios, the diesel engines emit low carbon monoxide (CO) and hydrocarbon (HC). However, they suffer from relatively higher oxides of nitrogen (NO_x) and smoke and this smoke emission is more at transient condition as compared to steady state [John B, 1988].

Adequate literature is available related to combustion in the diesel engine, modeling of the soot formation during steady state running of the engine [Aghav et al., 2006]. Also some experimental work is carried out to know the soot formation mechanism and the efforts are put to suggest some design modifications to reduce smoke in steady state [J. Benajes et al., 2004]. But the analysis of soot formation during transient running is not been so focused and very less literature is available, which is basically related to measurement of the smoke on time basis [Y.Cui, 2015]

There are different types of transient condition in various applications. In this work, the term transient will be used to describe sudden changes in load and speed during particular

operation. This condition is observed in maximum type of off-road vehicles which are used as construction equipment and main reason for this is turbocharger lag. This lag occurs when fuel delivery is rapidly increased. There is a brief period of time when the turbocharger fails to extract enough energy to supply enough air (to match the proper A/F ratio) resulting in transient black smoke (unburned fuel). Turbocharger lag depends on different design parameters of turbocharger. These are size of turbine housing, speed of compressor wheel, material of compressor and turbine wheel, etc.

The aim of this work is to study the reasons of high smoke during the transient condition and subsequently to suggest some modifications in order to minimize smoke.

## 2. METHODOLOGY

To construct AVL Boost simulation model for steady state working with AVL MCC combustion model, normalized rate of injection (NROI) and validate at from working speed range 1200-2200rpm. The results to be compared are power, specific fuel consumption, and mass of airflow, exhaust temperature and opacity.

To construct AVL Boost simulation model for transient operating mode with engine control unit (ECU) by using AVL MCC combustion model, normalized rate of injection (NROI) and full model of turbocharger and validate by using smoke opacity values, air flow data and performance maps.

To extend the validated transient simulation model to predict smoke performance of the engine during transient condition.

Provide guidelines to improve smoke during particular condition for turbocharged engine.

Conduct simulation trials with mentioned modification and further validate by experimentations with full throttle

performance (FTP) and transient emission test.

### 3. EXPERIMENTAL ENGINE DETAILS

A four cylinder diesel engine of heavy-duty application was selected for investigation. The method of aspiration is turbocharged. The engine is having mechanical fuel injection system. The details of engine are given in following table.

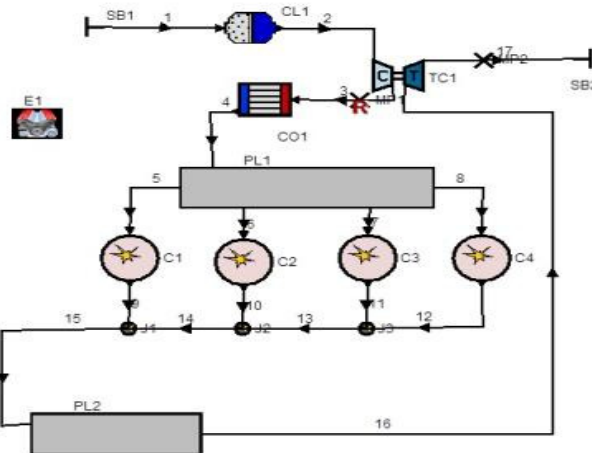
**TABLE 1: Engine Details**

Parameter	Type	Bore	Stroke	Compression Ratio	Cylinders
Value	DI diesel engine	105 mm	120 mm	17.5	4
Parameter	Rated RPM	Power	Fuel Pump	Nozzle Diameter	Aspiration
Value	2200	96 hp	Rotary	0.19	Turbocharged

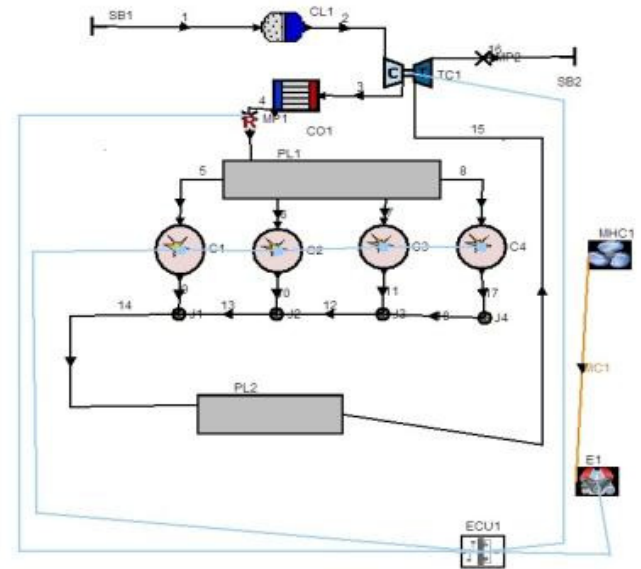
### 4. SIMULATION MODEL AND EXPERIMENTAL SETUP

In transient model, electronic control unit, full model of turbocharger, mechanical consumer is used. The ECU controls the fuelling of the engine to achieve the required speed and load variation depending on throttle demand. The mechanical consumer used for consuming energy generated which is important element for transient condition. Full model turbocharger includes detailed inputs of turbocharger like compressor and turbine performance map, its wheel speeds, inertia, etc. All these are the main inputs required to concentrate for transient smoke emission. The model was first stabilized for initial conditions and restart files were generated. Then the restart file was used as initial condition of the parameters for transient operation.

AVL Boost thermodynamic simulation model for steady state and transient state is shown in fig. 1 and fig. 2 respectively.



**Fig. 1. AVL Boost Thermodynamic Simulation Model for steady state**



**Fig. 2. AVL Boost Thermodynamic Simulation Model for transient state**

Experimental set up consists of experimental engine, dynamometer, indicating system and smoke measuring device with high speed data acquisition system. The cylinder pressure was measured using uncooled AVL piezoelectric pressure transducer of type GM11D. The line pressure was measured using strain gauge type pressure transducer from AVL of type 31DP2000-2.0, GG0443. The needle lift was measured using in built linearly variable differential transformer, LVDT in the injector. The crank angle position was sensed using AVL encoder of type 364-angle encoder. The stator of the encoder is fixed to the engine crankcase rigidly and the shaft is coupled to the crank pulley. Each degree of crank angle is further divided into four equal parts electronically to increase resolution.



The important parameters measured are power, speed, air flow, opacity, volumetric efficiency, specific fuel consumption. The air flow is measured by air flow meter of hot wire anemometer type, and smoke is measured with AVL 439 Opacimeter which is capable of transient smoke measurement [7]. An experimental set up as shown in fig: 3.



Fig. 3. Experimentation setup

## 5. TEST CYCLE

Transient test cycle is as shown in fig. 4. This is the operation actually observed in end application. At the

particular condition shown in figure, end application shows very high values of smoke and to carry out this operation we selected this particular test cycle which is similar to end operation.

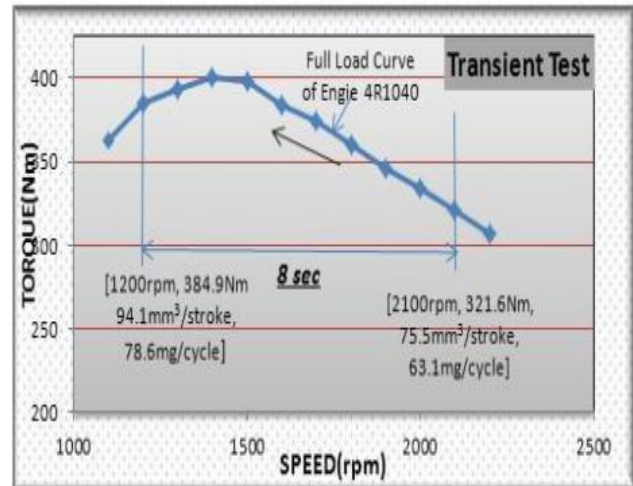


Fig. 4. Transient test cycle

## 6. RESULTS AND DISCUSSIONS

Old and new turbochargers from compressor side are shown in fig. 6 and fig. 7 respectively. New turbocharger has reduced compressor wheel diameter and turbine housing and having air guiding surfaces.

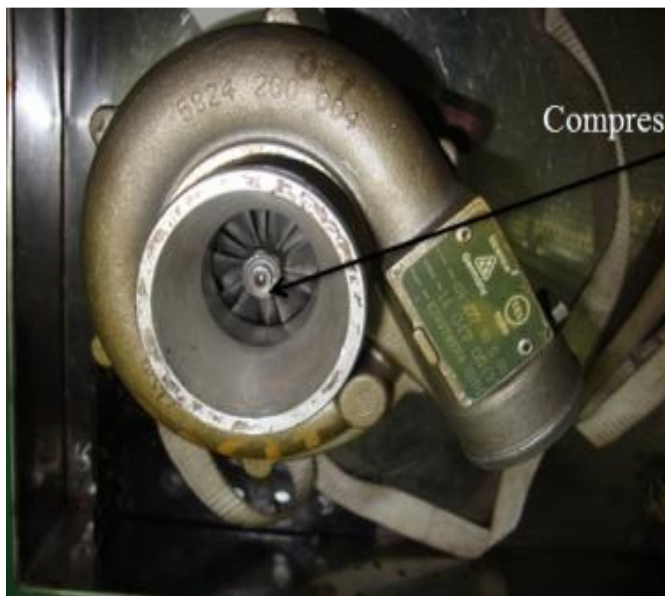


Fig. 5. Old turbocharger

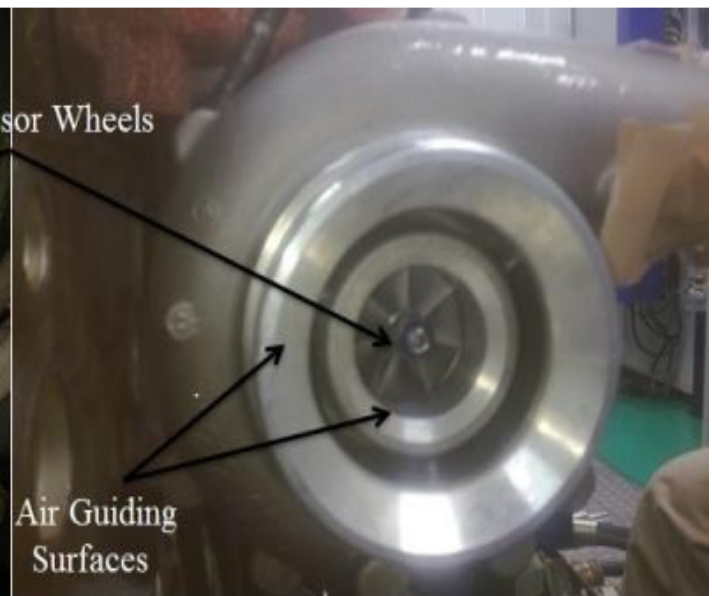
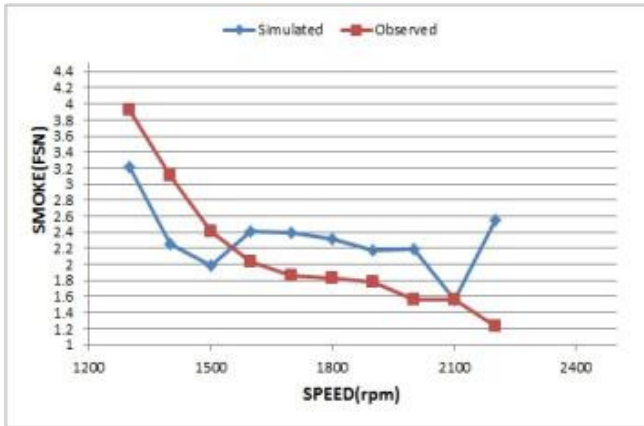


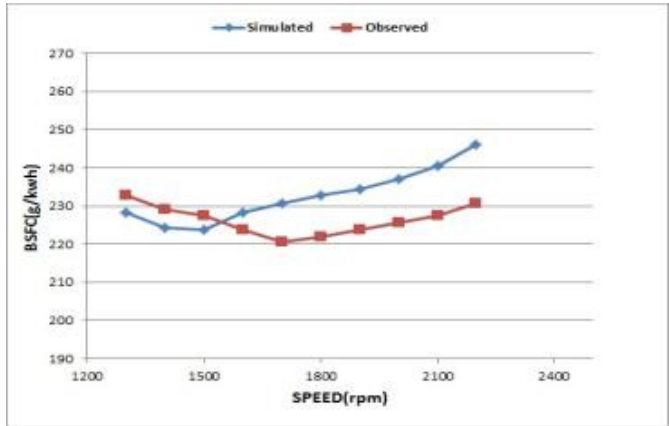
Fig. 6. New turbocharger

The engine is tested at different speed and load and steady state data related to engine and turbocharger is collected. The data collected is used to compare the steady state simulation results. The model is tuned so that the simulation results reasonably matches with the measured values for low to high speed range of the engine.





**Fig. 7. Comparison of simulated and measured smoke**



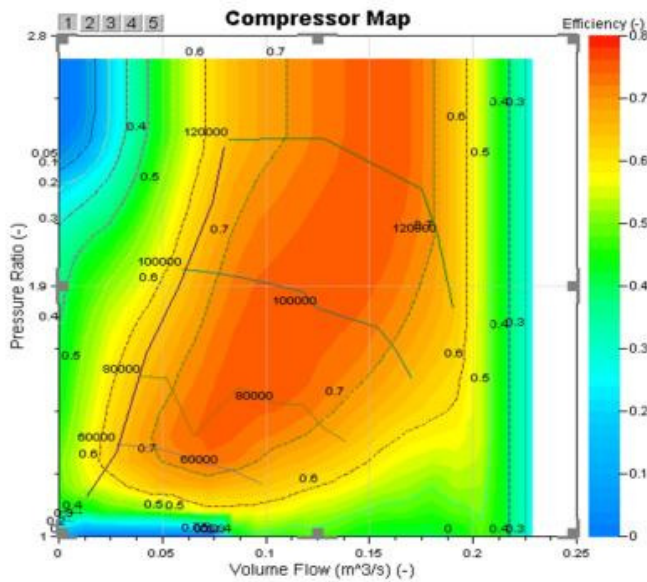
**Fig. 8. Comparison of simulated and measured bsfc**

Fig. 7 and fig. 8 indicate validity of steady state simulation model of the engine. Soot obtained by simulation is in g/kw-hr unit, converted into smoke with HSU (hartridge smoke unit) and further converted into FSN (filter smoke number) using MIRA correlations [MIRA, 1965].

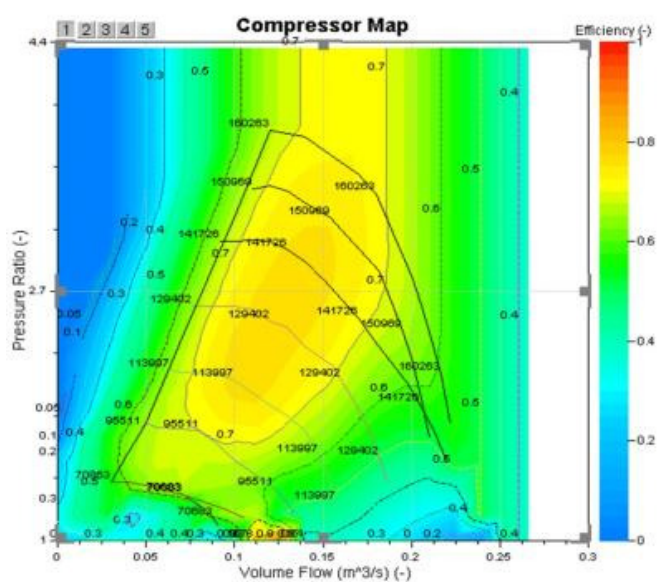
After steady state test, engine is tested at transient condition

related smoke values, load and speed variations with respect to time is recorded.

Fig 9 shows compressor performance map of old turbocharger with less speed limit of compressor wheel and fig 10 shows compressor performance map of new turbocharger with increased speed range of compressor wheel.

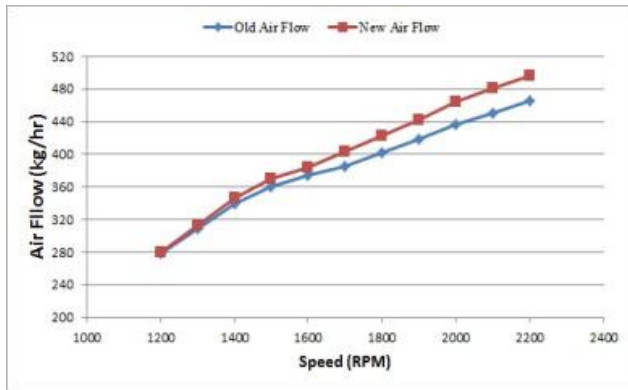


**Fig. 9. Old compressor performance map**



**Fig. 10. New compressor performance map**

Fig. 11 shows increased quantity of air flow with new turbocharger at steady state. Fig. 12 shows decreased smoke values at transient condition.



**Fig. 11. Improved air flow**

## 7. CONCLUSION

Steady state and transient simulation models of the engines are validated by comparing experimental data and simulated results. The transient simulation model is mainly validated based smoke values and turbocharger performance maps.

Transient simulation model of the engine is validated by comparing simulated results with experimental results. It is mainly validated for speed and smoke variation during transient condition.

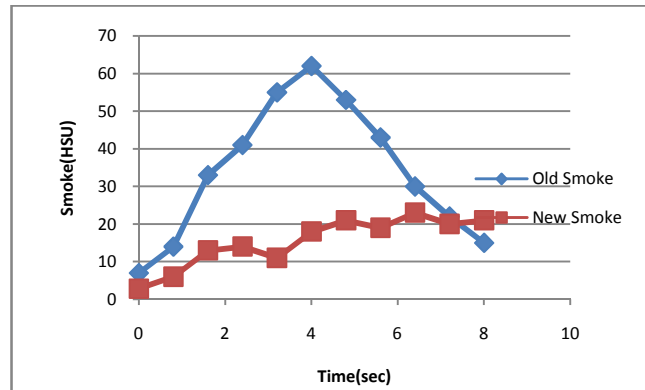
Due decreasing compressor wheel diameter, turbine housing and increasing speed of turbine, improvement in air flow is obtained which helped to reduce the smoke emission.

The smoke emission is optimized because these parameters help for complete combustion and decreasing turbocharger lag.

These are very cost effective technique these techniques for engines with mechanical fuel injection system and these techniques can be used for smoke reduction at transient operation in DI Diesel engine of off-road vehicles.

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**Fig. 12. Reduced smoke value**

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# Design and Analysis of the Any Way Commuter: The Modern Day Floating Human Powered Vehicle

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**Abstract:** Floods crosswise over many parts of the India have wreaked devastation bringing about mayhem in a few ranges. The flood toll has achieved an incredible 200 and a couple of thousands have turned out to be destitute according to the information of July, 2017. Considering the flood issues in India as of late, idea of vehicle named as "Any Way Commuter" (AWC) which can go on both major modes of transportation: Road way and Water way. Essentially it falls in the class of amphibious vehicle which is distinguished as a vehicle that is means for transport, viable on land and additionally on (or under) water. This vehicle is exclusively fuelled mechanically keeping in mind the end goal to disregard natural issues. Aside from flood rescue application AWC can be utilized as a water riding bicycle for amusement purposes as an environmental water riding. Mechanical structure attachment in AWC skims it on water surface and keeps up the centre of gravity while riding.

**Keywords:** Amphibian, Floating Bicycle, Commuter, Human Powered Vehicle

## 1. INTRODUCTION

The possibility of a water bike is not late start and has been around for over a century. Until 1890 the water bike framed its place ever. The water bike for the most part chipping away at Archimedes' principle. Buoyancy is a force implied by a fluid that be in conflict with object's weight. Buoyancy can likewise be expressed as the weight of moved body. Weight in a fluid ascends with profundity because of the weight of the covering fluid (hydrostatic weight). Consequently a body submerged in a fluid encounters higher pressure at the bottom of the fluid than at the topmost. This difference in pressure brings about a net force that has a tendency to hasten an object upwards.

### 1.1 Working Principle

From Figure 1 it can be found there are four different cases for understanding of Archimedes' principle.^[1]

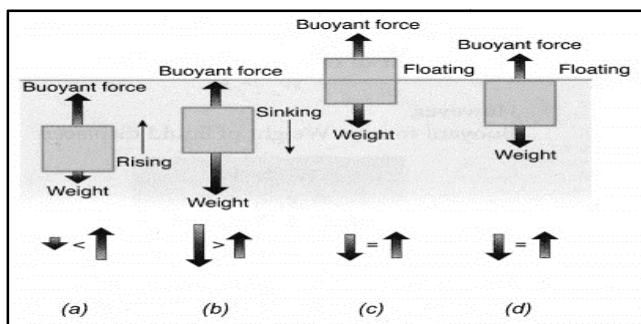


Fig. 1. Principle of Floating

**Case (a)** If the Buoyant force is greater than the weight of body then the body will be in rising condition.

**Case (b)** If the Buoyant force is less than the weight of body then the body will be in sinking condition.

**Case (c)** If the Buoyant force is equal to weight of body and body is partially submerged inside water surface then the body will be in Floating condition.

**Case (d)** If the Buoyant force is equal to weight of body and body is submerged inside water surface then the body will be in Floating condition.

For water bicycle the same principle will be applicable. When the supporting tube (bottom part of bicycle) is submerged in water at that time some amount of buoyant force in upward direction is acting on body which will be equivalent to the weight of the fluid. Hence the body move upward due to buoyant force which acts at the center of mass of the moved fluid.

The working of water bicycle in such way that as the rider give power to pedal. Whatever power is given by rider it is directly supply to propeller which is connected with bicycle. As power is transmitted to propeller so rotation of propeller start inside the water surface and the bicycle move in forward direction.

The paper comprises of working principle, rational design calculations, floating analysis and their relevant outcomes.

## 2. LITERATURE REVIEW

The overview of literatures is discussed here. The invention is identified with water cycle and its prime objective is to give a pedal worked vehicle by which at least one person may go upon the surface of a lake, waterway or other moderately smooth waterway, Angelo. The water bike has a pedal apparatus and a bicycle kind of transmission controlling a propeller situated at the back of the water bike. The primary body part is same as straightforward bicycle while at end it is having pedal drive propeller get together. This propeller assembly is at whatever point it is required to dismantle for easy disassembly. Likewise the support extension for the pedal drive assembly is equipped for the operator after that buoyancy has been built up with the setup David Vigo, 1940. The Propeller assembly is organized to turn rearward for easy ride over water surface.

## 3. DESIGN METHOD

The main design aspect comprises the design of transmission system and propulsion system. These two systems are main criterion for the efficiency of AWC while driving on water surface.

### 3.1 DESIGN OF TRANSMISSION SYSTEM V.B. Bhandari

Step 1: Single strand Roller Chain Standard chain for bicycle – 08B (British standard).

So Pitch (P) is 12.7 mm.

Step 2: Took optimized gear ratio of 3:1.

Step 3: Opted No. of teeth on driving sprocket  $Z_1 = 42$

No. of teeth on driven sprocket  $Z_2 = 14$

Step 4: Pitch angle ( $\alpha$ ) =  $\frac{360}{Z}$  ... (i)

Front Sprocket =  $8.57^\circ$

Rear Sprocket =  $25.71^\circ$

Step 5: Diameter of Sprocket

$$D_s = \frac{P}{\sin(\frac{\alpha}{2})} = \frac{1270}{\sin(\frac{8.5714}{2})} \dots \quad \text{(ii)}$$

$$= 171.62 \text{ mm}$$

Step 6: Find the Cog rpm

$$I = \frac{N_1}{N_2} = \frac{Z_2}{Z_1} \dots \quad \text{(iii)}$$

Where I = Velocity ratio

$$= \frac{80}{N_2} = \frac{14}{42}$$

$$N_2 = \frac{80 \times 42}{14} = 240 \text{ rpm}$$

Step 7: Velocity of Chain

$$V = \frac{ZP N}{60 \times 1000} \dots \quad \text{(iv)}$$

$$= \frac{14 \times 12.7 \times 240}{60 \times 1000}$$

$$= 0.7112 \text{ m/s}$$

Step 8: Power Required For Cog

For pinion Speed ( $N_2 = 240 \text{ RPM}$ )

$$P = \frac{2\pi NT}{60} \dots \quad \text{(v)}$$

$$P = \frac{2 \times 3.14 \times 240 \times 48.10}{60}$$

$$P = 1.2082 \text{ KW}$$

Step 9: No. of link in chain

$$N_L = 2 \frac{a}{p} + \frac{Z_1 + Z_2}{Z} + \left( \frac{Z_2 - Z_1}{2\pi} \right)^2 \frac{p}{a} \dots \quad \text{(vi)}$$

$$N_L = 100$$

### 3.2 Design of Propulsion System

The movement AWC is possible by the rotation of propeller. Intentionally Al – 6061 is kept as a material of propeller. Initial Parameters for propeller are taken as a trial.

Diameter d = (15 to 20 inch)

No. of Blade = 4

Front RPM = 80 (General rotations implied by normal person)

Rear RPM = 240

Force = 1100 N

Crank Diameter = 0.1905 m

Here the calculation is for the 20 / d

Torque acting on propeller

$$T = F \times D \dots \quad \text{(vii)}$$

$$= 1100 \times 0.1905$$

$$= 209.55 \text{ N.m}$$

Power transmitted by propeller

$$P_p = \frac{2\pi NT}{60} \dots (\text{viii})$$

$$= \frac{2\pi \times 240 \times 209.55}{60}$$

$$P = 5.26 \text{ KW}$$

$$\text{Angular Velocity } \omega = \frac{2\pi N}{60} \dots (\text{ix})$$

$$= \frac{2\pi \times 3.14 \times 240}{60}$$

$$= 25.12 \text{ rad / s}$$

Required Number of Blade is 4.

$$\frac{AE}{Ao} = 0.43 \times \text{No. of Blades} \times \frac{\text{Blade width}}{d} \dots (\text{x})$$

$$= 0.43 \times 4 \times \frac{3.2}{20}$$

$$\frac{AE}{Ao} = 0.2752 \text{ (It is ratio of expanded Area to swept area)}$$

It should be kept least to obtain the higher displacement of water done by propeller.

**TABLE 1: Comparison of inner diameter of propeller**

Inner Diameter [d] (m)	$\frac{AE}{Ao}$
15	0.36
16	0.33
17	0.31
18	0.29
20	0.28

#### 4. ANALYSIS

In the presented work, the standard procedure was followed. First, the necessary mathematics was performed and the floating principle, metacentric height and others such boundary conditions were obtained and the subsequent analysis were performed on software and simulation platforms.

##### 4.1 Floating Analysis

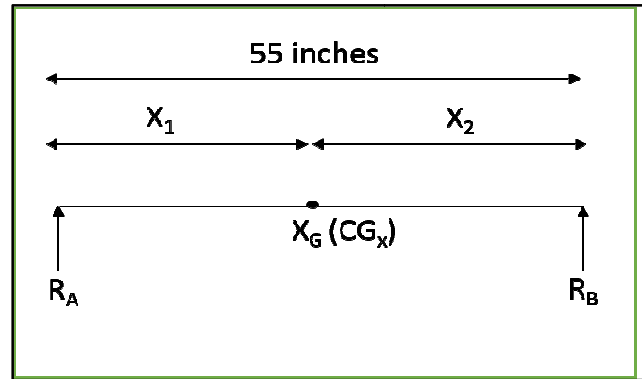
Here, taking the moment about centre of gravity point  $X_G$  for the center points of front and rear wheel at baseline.

$$X_1 + X_2 = 55 \text{ inches}$$

$$X_1 + X_2 = 1397 \text{ mm} = 1.397 \text{ m}$$

$$X_2 = 1.397 - X_1$$

$$R_A X_1 + R_B X_2 = 0 \dots (\text{xi})$$



**Fig. 2. Position of Centre of Gravity**

Here,  $R_A$  and  $R_B$  are the 40% & 60% of total load (1300 N) respectively.

$$\text{So, } R_A = 585 \text{ N, } R_B = 780 \text{ N}$$

$$\text{Now, } -585 X_1 + 780 (1.397 - X_1) = 0$$

$$-585 X_1 + 1089.66 - 780 X_1 = 0$$

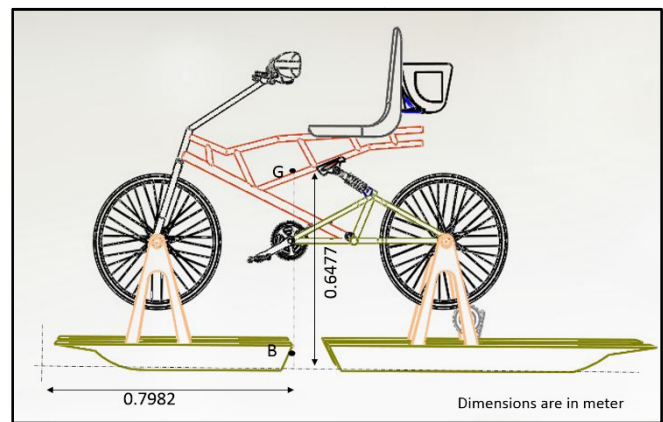
$$1089.66 = 1365 X_1$$

$$X_1 = 0.7982 \text{ m (31.42 inch)}$$

$$X_1 + X_2 = 1.397 \text{ m}$$

$$X_2 = 1.397 - 0.7982 = 0.5988 \text{ m (23.57 inch)}$$

So, Horizontal Component of Center of Gravity  $X_G = 0.7982 \text{ m}$ .



**Fig. 3. Centre of Buoyancy, Centre of Gravity of AWC**

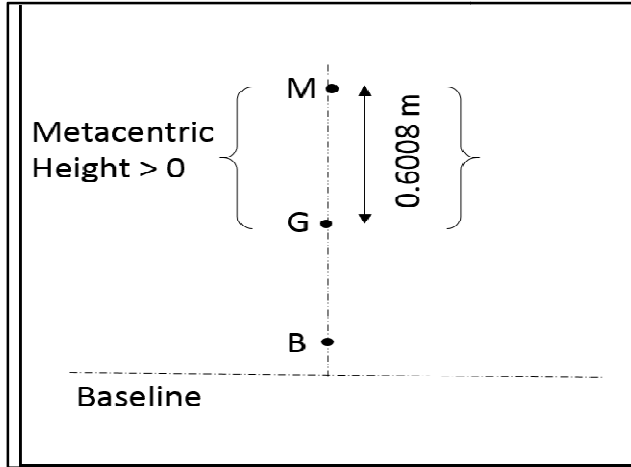
Total Height of AWC is 1.2954 m.

So, Vertical Component of Center of Gravity is 0.6477 m.

$$\text{Hence, } Y_G = 0.6477 \text{ m}$$

Here Height of Submerged Part of AWC = 0.113 m

$$\text{Distance of Center of Buoyancy is } Y_B = 0.113 / 2 = 0.00565 \text{ m}$$



**Fig. 4. Metacentric Height of AWC**

Weight of displaced water = Weight of submerged part of AWC.

$$W = w \quad \dots \quad (xii)$$

$$Mg = w$$

$$\rho_w \times V_d \times g = w$$

$$V_d = \frac{w}{\rho_w g} \quad \dots \quad (xiii)$$

$$= \frac{1300}{1000 \times 9.81}$$

$$V_d = 0.1325 \text{ m}^3$$

$$I = \frac{bl^3}{12} - \frac{l^3 b_1}{12} \quad \dots \quad (xiv)$$

$$= \frac{(0.8128)(2.032)^3}{12} - \frac{(2.032)^3(.04064)}{12}$$

$$= 0.5683 - 0.3244 = 0.2439 \text{ m}^4$$

$$MB = \frac{I}{V_d} \dots \quad (xv)$$

$$= \frac{0.2439}{0.1325}$$

$$= 1.8406 \text{ m}$$

$$Y_m = Y_B + MB \quad \dots \quad (xvi)$$

$$= 0.0556 + 1.8406$$

$$= 1.8963 \text{ m}$$

Degree of Stability,

$$MG = Y_m - Y_G \dots \quad (xvii)$$

$$= 1.8963 - 1.2954$$

$$= 0.60082 \text{ m} > 0 (\text{Positive})^{[6]}$$

Here, from above calculation Metacentric Height (GM) is positive which shows that it is above the center of buoyancy (B). This is the mathematical validation of floating for body which also results in the favourof AWC.

#### 4.2 Floating Simulation in ANSYS

Propulsion simulation of rotor (propeller) is performed in ANSYS 17.0 Student Version, in which ANSYS FLUENT is opted to run the simulation of propulsion in water as a fluid. Meshing and simulation is shown in Table 2. Velocity of water at inlet will be negligible as in boundary conditions steady water is taken for the simulation.

**TABLE 2: Meshing & Simulation Date**

Meshing Information	
Mesh Type	Tetrahedron
Encloser Nodes	3036
Encloser Elements	15858
Rotor Nodes	13755
Rotor Elements	65638
Simulation	
Equations	10
Cycles	100

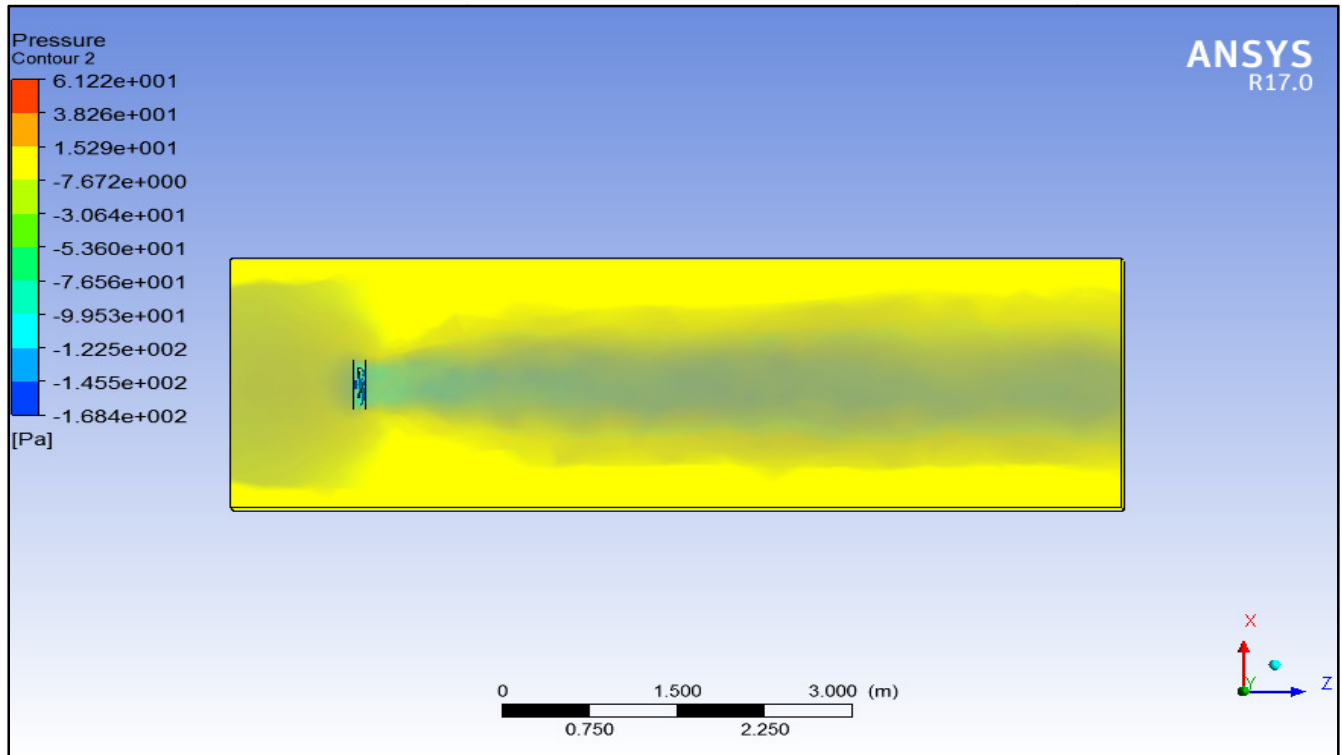


Fig. 5. Pressure Contour During Propulsion

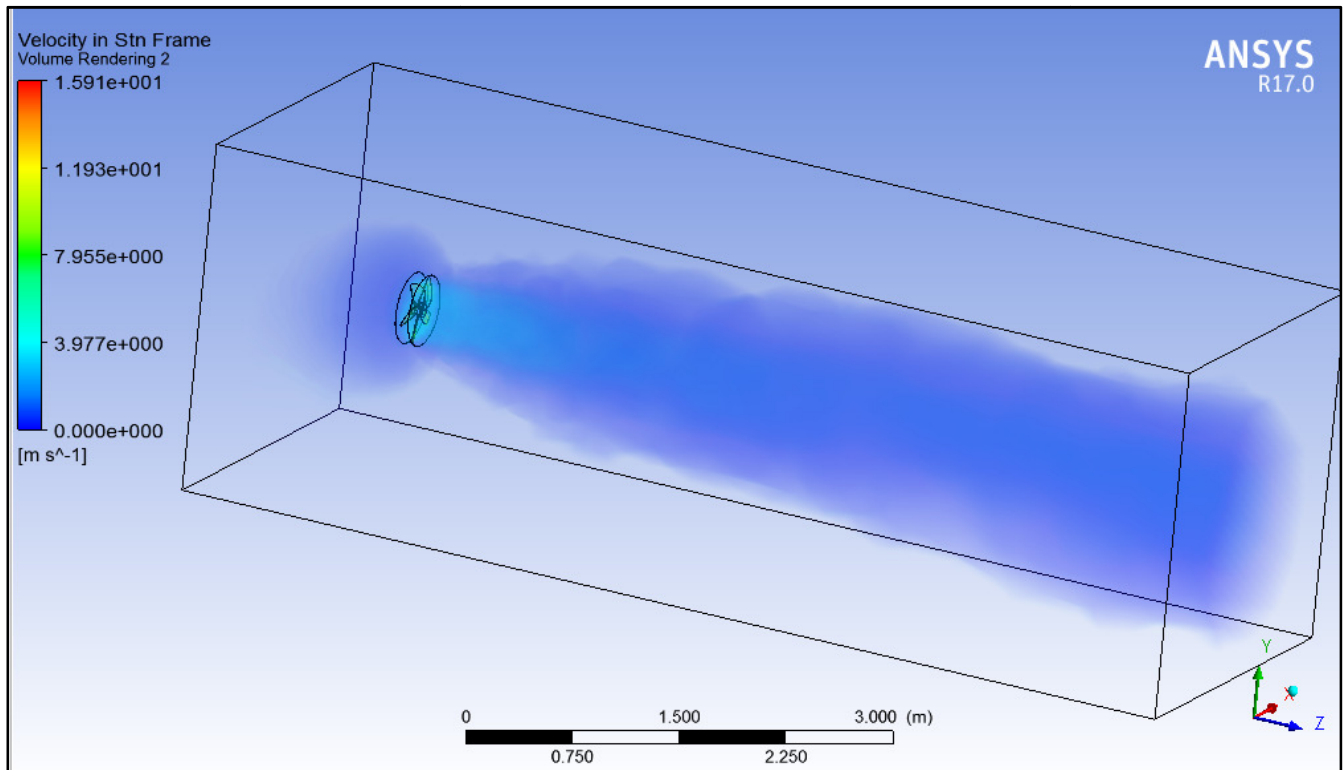


Fig. 6. Pattern of Thrust



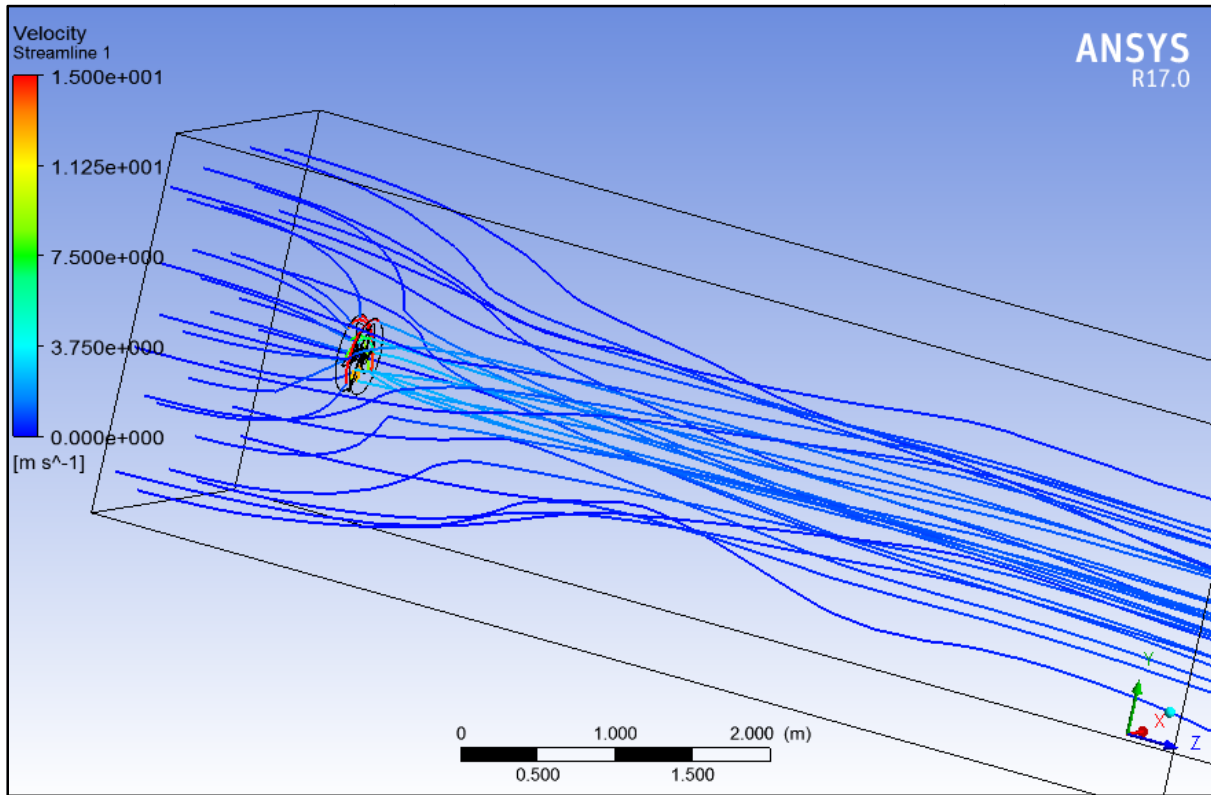


Fig. 7. Streamlines During Propulsion

TABLE 3: Results of Simulation

Results	
Outlet Velocity	15.91 m/s
Maximum Pressure	15.29 Pa

## 5. CONCLUSION

Any Way Commuter (AWC) is viable for water riding as calculative and analytical results are in the favour. Metacentric Height(GM) is 0.60082 m (positive) and above the Centre of Gravity which proves the principle of stability and floatation. So, design of Any Way Commuter(AWC) is also validated. Simulation of propeller gives the appropriate velocity of rotor and pressure generated by it during the propulsion. Practical floating test has been carried out on primary model and final model will be modified as per the results.

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## 6 NOMENCLATURE & ABBREVIATION

$\frac{AE}{Ao}$  - Ratio of expanded Area to swept area

AWC – Any Way Commuter

b – Breath of Supporting Base of AWC

b₁ – breath of supporting tube

d - Inner Diameter of Propeller

D – Crank Diameter

D_s - Diameter of Sprocket (mm)

F – Force implied by Pedal (N)

I – Least moment of area

L – Length of supporting base AWC

M – Mass of displaced water



MB – Height of centre of buoyancy from baseline

MG – Metacentric height

$N_1$  – Angular Speed of Driving Sprocket

$N_2$  – Angular Speed of driven Sprocket

$N_L$  – Number of Links in Chain

P – Pitch of Chain (Mm)

P – Power required for Cog

$P_p$  – Power transmitted by propeller

$R_A$  – Reaction Force at Front Wheel Center

$R_B$  – Reaction Force at Rear Wheel Center

V – Velocity of Chain (m/s)

$V_d$  – Volume of Displaced Water

w – Weight of submerged body of AWC

W – Wight of displaced water

$X_1$  – Distance of Front Wheel from Center Of Gravity

$X_2$  -Distance of Rear Wheel from Center Of Gravity

$X_G$  – Horizontal Component of Center Of Gravity

$Y_G$  - Vertical Component of Center Of Gravity

$Y_M$  – height ofmetacentric point from baseline

$Z_1$  _No. Of Teeth of Driving Sprocket

$Z_2$  _No. Of Teeth of Driven Sprocket

$\alpha$  – Pitch Angle ( $^{\circ}$ )

# Line Efficiency Improvement of Fuel Level Sensor Line

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**Abstract:** A pre-requisite to profit maximization and productivity improvement is the existence of production norms, optimal balancing of assembly lines and efficient layouts. The paper presents a case study of productivity improvement at Fuel Level Sensor (FLS) assembly line at auto-components manufacturing company a Tier-I supplier to OEMs. It illustrates the application of industrial engineering concepts viz., time study for establishing production norms, line balancing, multi-machine manning and modifications in layout to ensure optimal utilization of resources (manpower, machines and space). The improvements were implemented after the feasibility check. The paper concludes with results after implementing the improvements on the assembly line.

**Keywords:** Time study, Line Balancing, Manpower reduction, Takt time

## 1. INTRODUCTION

The company is Tier I supplier of FLS to major OEMs in Automobile industry. The FLS assembly line produces large quantity of Fuel Level Sensors for many MNC's. Monthly production requirement is around 35, 750 units. There are 9 work stations and 2 sub-stations. The line was facing following problems:

- High level of imbalance in work content at various work stations
- Improper material flow and excess utilization of space

## 2. METHODOLOGY

The following approach was adopted to improve the productivity on the line:

1. Data collection on assembly line
2. Analysis of data and manpower allocation on the line
3. Line Balancing according to Takt time

### 2.1 Data collection on assembly line

Cycle time broken down in elements was collected for each work station using Time Study. In all 15 cycles were measured on each workstation to have accurate and precise data. Performance rating and allowances were added to observed time to arrive at standard time required as each workstation based on operator's efficiency and speed. Manpower allocation in the present system and manpower requirements were assessed to determine over-, under-utilization.

### 2.2 Analysis of data and manpower allocation on the line

Elemental time study was done to find determine standard time to perform an operation on each workstation. The objective was to find manual work content of operator and line imbalance and assess capacity utilization. was also analysed on each workstation. Table 1 shows the elemental time study.

Based on the monthly demand, takt time and target manpower was calculated. Time in which one product is to be made to meet the demand is called Takt time. The average demand of the line is 35750 units/month. The line works 25 days/ month and 16 hrs/day.

TABLE 1: Element Time Description

Operation No.	Element Description	Type of work	Std. time in secs.		W/s Std. time (Secs.)	Manpower allocation	Operation time (Secs.)
			Manual	Machine			
	Leakage testing				28.30	1	33.89
1.1	Place on the fixture	Manual	10.20				
1.2	Check the work piece	Machine		16.00			
1.3	Remove and move to next w/s	Manual	2.10				
	Date Stamping				5.60		
2.1	Place on the fixture	Manual	3.47				
2.2	Perform machining & put in bin	Manual	2.13				

	Soldering (Connecting wires with housing)				12.89	1	12.89
3.1	Place on the fixture	Manual	6.52				
3.2	Soldering wires to housing	Manual	5.28				
3.3	Remove and move to next w/s	Manual	1.09				
	Lever float driving				10.53	1	10.53
4.1	Place on the fixture	Manual	6.69				
4.2	Perform machining & put on next w/s	Manual	3.84				
	Housing assembly and screwing				16.91	1	16.91
5.1	Place on the fixture	Manual	7.49				
5.2	Assemble & put on next w/s	Manual	9.42				
	Soldering (Terminal with wire)				11.01	1	11.01
6.1	Place on the fixture	Manual	2.44				
6.2	Soldering terminals	Manual	7.61				
6.3	Remove and move to next w/s	Manual	0.96				
	Resistance checking				14.62	1	14.62
7.1	Connect to pokayoke	Manual	4.93				
7.2	Check the resistance	Manual	7.52				
7.3	Place on the next w/s	Manual	2.16				
	Resistance and smoothness inspection & Visual inspection				13.69	1	13.69
8.1	Connect to pokayoke	Manual	7.78				
8.2	Check the work piece	Machine		4.80			
8.3	Move to next w/s	Manual	1.11				
	Final inspection				16.06	1	16.06
9.1	Connect to pokayoke	Manual	6.14				
9.2	Check the work piece	Manual	9.44				
9.3	Put in the bin	Manual	0.47				
Sub-assembly line							
	Spring contact with holder & contact pressure check				15.82	1	15.82
10.1	Assemble & place on machine	Manual	2.26				
10.2	Machine operation	Machine		10.00			
10.3	Assemble	Manual	1.06				
10.4	Put in the bin	Manual	2.50				
	Lever float crimping				9.92	1	9.92
11.1	Assemble & place on fixture	Manual	6.96				
11.2	Perform machining and put in bin	Manual	2.96				

Summary of Calculations:

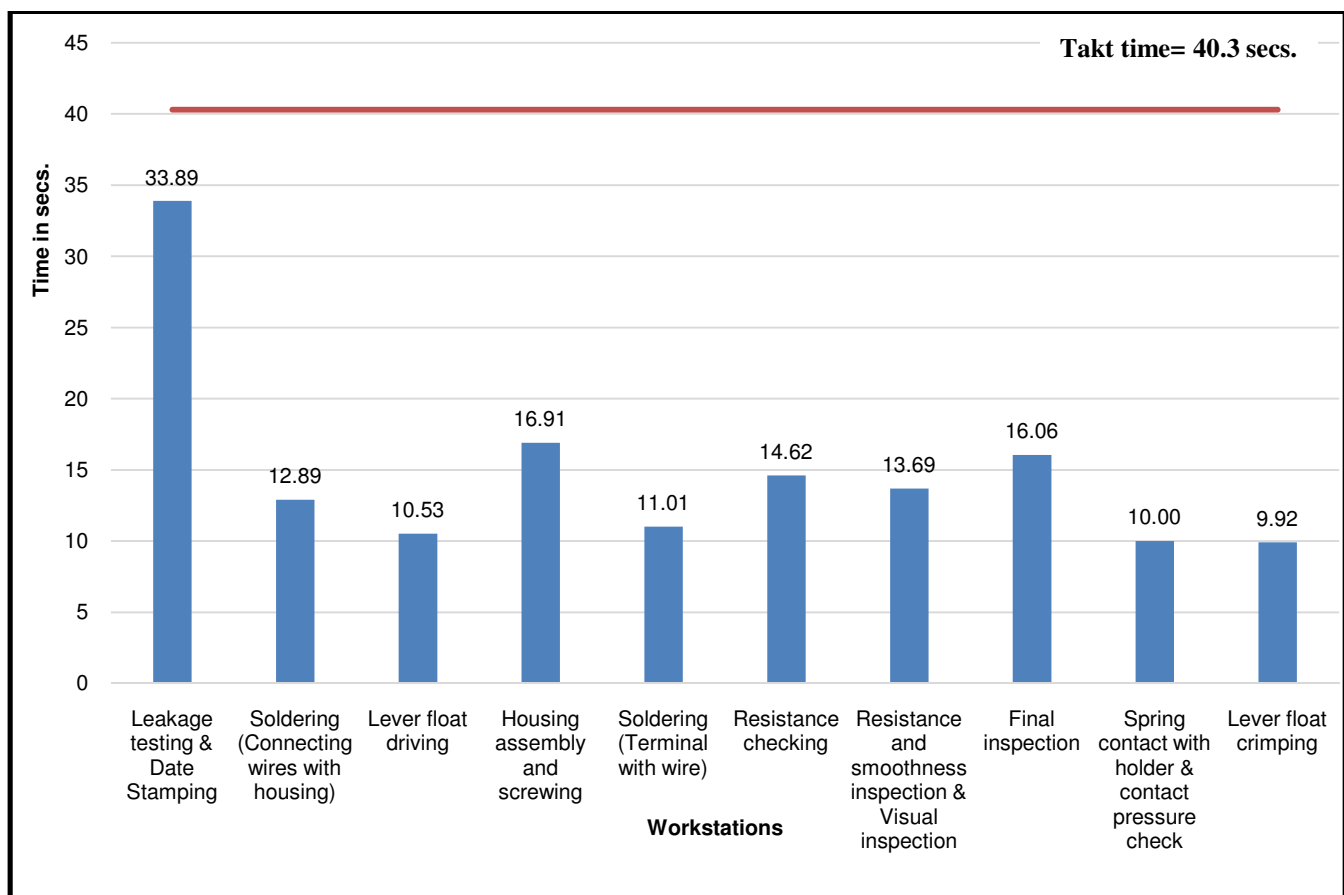
Takt time =	Available time	=	25*16*3600	=	40.3 sec
	Total demand		35750		

Total work content : 155.36 sec  
 Manpower used : 10  
 Output per hour per operator : 11 units

Balance delay =	Total idle time *100	=	183.58*100	=	54.16
	No. of w/s *cycle time		10*33.89		

Target manpower is the number of operators required to work on the line if work could be divided evenly among the operators. The target manpower cannot be achieved as it is not always feasible to divide the work evenly among operators.

Target manpower =	Total work content	=	155.36	=	4
	Takt time		40.3		



**Fig. 1. Work content distribution w.r.t Takt time (Present method)**

As shown in figure 1, although the maximum cycle time is less than Takt time, it is evident from the above figure and calculation of balance delay that there is enough scope for optimizing the manpower and reduction in cycle time at a few workstations.

Figure 2 shows the U-shaped layout of the assembly line. The operator takes housing from the I/p bin, checks it on the m/c (w/s 1) and stamps the date next w/s 2. The next

operator solders the wires with housing (assembly 1) on w/s 3. Lever float and the electronic chip from w/s 10 and w/s 11 respectively, are assembled together (assembly 2) on w/s 4. This assembly 2 is then mounted on the housing on w/s 5. The terminals of chip are soldered to wires at w/s 6. W/s 7 and 8 check the functioning of FLS. After final checking on w/s 9 the product is kept in o/p bin. Chip is assembled on w/s 10. The float is attached to small rod on w/s 11.

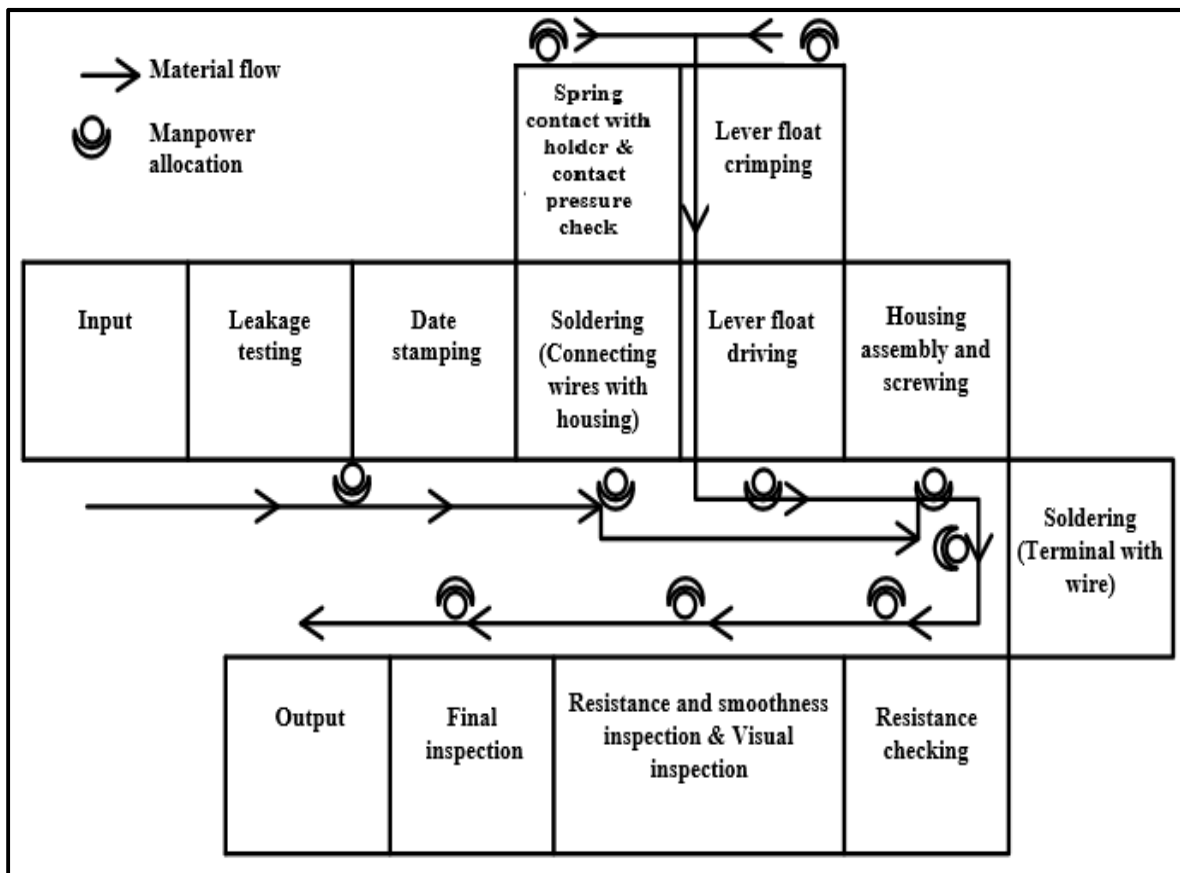


Fig. 2. Original Layout of Assembly Line

### 2.3 Line Balancing

Figure 1 shows the distribution of work content among the operators. It was observed that excess of manpower was deployed on the line. This was reduced by combining some workstations and allocating single manpower at those workstations. Care was taken that cycle time does not exceed the Takt time and it is feasible for person to perform the combined operations. Another issue was discontinuous

material flow at lever float driving station as shown in Figure 2. The lever float driving station was shifted to sub assembly line to ensure efficient material flow and reduce material handling. Table 2 shows the implemented manpower allocation. Figure 3 shows the comparison of present and proposed methods with help of a multiple activity chart. Figure 4 shows comparison of work content distribution w.r.t Takt time after implementation. Figure 5 shows the new layout of the line.

TABLE 2: Manpower Allocation Through Multi-Machine Manning

W/s No.	Workstation names	Std. time
1 & 2	Leakage testing Date Stamping	33.89
3 & 4	Soldering (Connecting wires with housing) Housing assembly and screwing	29.81
5 & 6	Soldering (Terminal with wire) Resistance checking	25.63
7 & 8	Resistance and smoothness inspection & Visual inspection & Final inspection	29.75
<b>Sub-assembly line</b>		
9 & 10	Lever float driving Lever float crimping	20.45
11	Spring contact with holder & contact pressure check	15.82

Workstation Analysis Using Multiple Activity Chart					Workstation Analysis Using Multiple Activity Chart				
Present Method			Proposed Method		Present Method			Proposed Method	
Time (sec)	Workstation 3: Operator 2	Workstation 5: Operator 4	Time (sec)	Merged Workstation: Operator 2	Time (sec)	Workstation 6: Operator 5	Workstation 7: Operator 6	Time (sec)	Merged Workstation: Operator 3
1	Soldering (connecting wire with housing)	Housing assembly and screwing	1	Soldering (connecting wire with housing)	1	Soldering (terminals with wire)	Resistance checking	1	Soldering (terminals with wire)
2			2		2			2	
3			3		3			3	
4			4		4			4	
5			5		5			5	
6			6		6			6	
7			7		7			7	
8			8		8			8	
9			9		9			9	
10			10		10			10	
11			11		11			11	
12			12		12			12	
13			13		13			13	
14	Soldering (connecting wire with housing)	Housing assembly and screwing	14	Housing assembly and screwing	14	Soldering (terminals with wire)	Resistance checking	14	Resistance checking
15			15		15			15	
16			16		16			16	
17			17		17			17	
18			18		18			18	
19			19		19			19	
20			20		20			20	
21			21		21			21	
22			22		22			22	
23			23		23	Soldering (terminals with wire)	Resistance checking	23	Soldering (terminals with wire)
24	Soldering (connecting wire with housing)	Housing assembly and screwing	24	Housing assembly and screwing	24			24	
25			25		25			25	
26			26		26			26	
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30			30		30			30	
31			31		31			31	
32			32		32			32	
33			33		33			33	
34			34	Soldering (connecting wire with housing)	34	Soldering (terminals with wire)	Resistance checking	34	Resistance checking
			35		35			35	
			36		36			36	
			37		37			37	
			38		38			38	
			39		39			39	
			40						
			41						

Fig. 3. Multiple Activity Chart (Merging Workstations – Multi Machine Manning Concept)

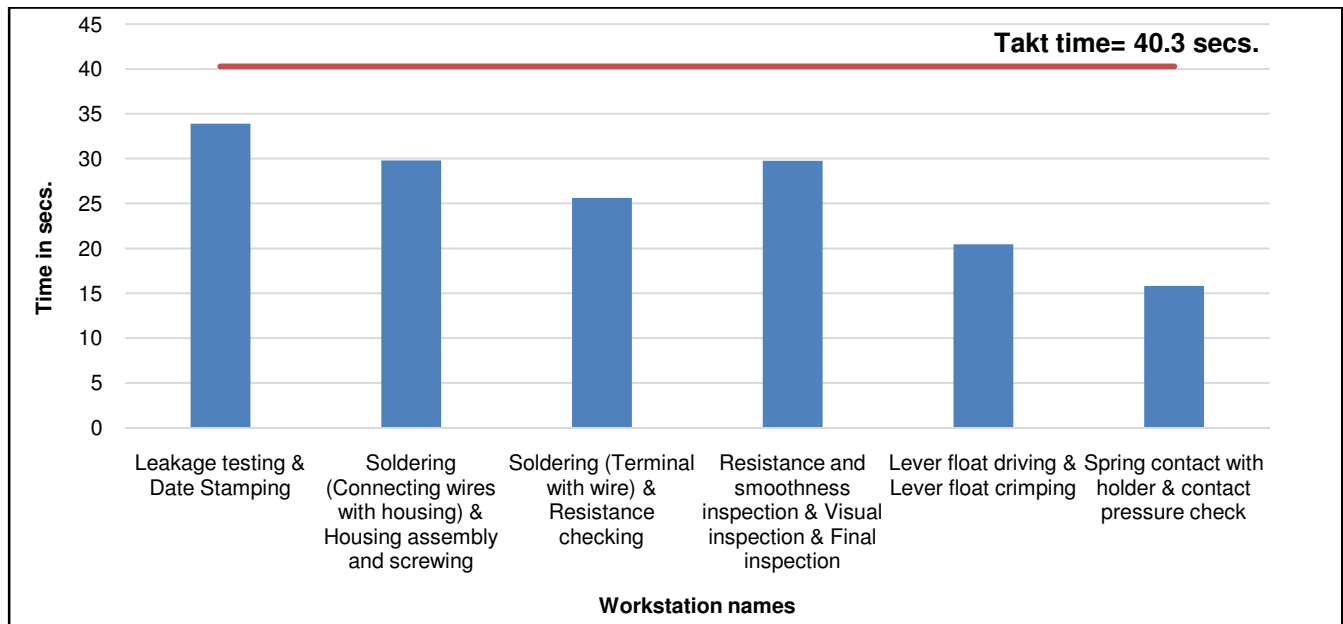


Fig. 4. Workstation time w.r.t. Takt time (Proposed method)

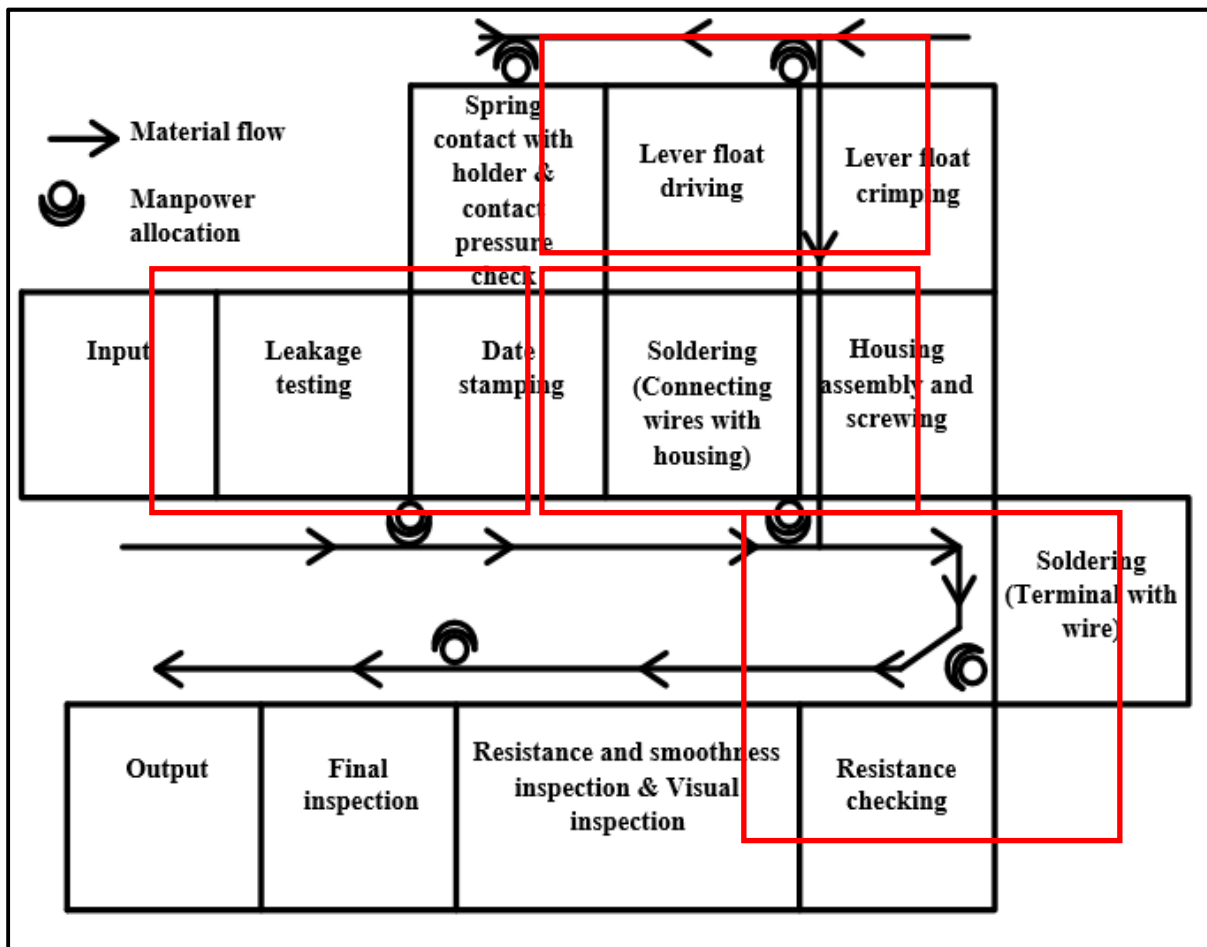


Fig. 5. Improved Layout of Assembly Line

### 3. RESULTS AND CONCLUSION:

The results of implementing the improvements is summarized in table 3.

**TABLE 3: Results of implementing the improvements**

	<b>Before Improvement</b>	<b>After Improvement</b>
Manpower allocation	10	6
Output per hour per operator	11	18
Balance delay	54.2%	23.61%

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# Design and Modification of Wheat Crop Cutting Machine

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**Abstract:** Today, Wheat crops occupies the prime position among the food crops in the world, In India, it is second important food crop being next to rice. Nowadays very few skilled labors are available for agriculture. Because of this shortage the farmers prefer to use crop cutting machine. These cutting machines are costly and only available of very large scale farming. However, agriculture groups make these available for rent on an hourly basis for small scale farmers. Taking into account the requirements of current situation, the idea is to prepare a machine which is cheap and will reduce the labor required to cut crops. In this machine, the high strength of straight cutting blade which helps to allow crops easily and cut the crops by shearing action. The movement of reciprocating motion of blade given by the Rack and pinion mechanism which gives the maximum cutting force to cut the crops. A collecting mechanism is provided for the collection of crops after cutting.

**Keywords:** Wheat crop cutting machine, Rack and pinion mechanism, collecting system

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## 1. INTRODUCTION

Farming is most widely followed profession in India. Agricultural products contribute a major portion to our economy. The crop cutting is important stage in agriculture field. Engineering science has brought tremendous changes in traditional crop cutting machines. However to increase our economic condition of small scale farmers, we must increase the productivity and quality of machines systems. Thus there is a need for the development of a compact and a comparatively cheap crop cutting machine which will be affordable to the small scale farmers. The focus of the project is to create a portable, compact and user friendly low cost mini crop cutter and collector machine which will simultaneously perform both jobs of cutting and collecting the crops. This machine is cost effective, easy to maintain and can be simply manufactured as it comprises of locally available spare parts.

The purpose of the modification of this machine is to find innovative solutions for simple crop cutting machinery that serves to multi-cereal commodities, lightweight, easy to operate, and has a relatively large cutting capacity.

## 2. LITERATURE REVIEW

Various approaches have been proposed for improving mechanized type of crop cutter in agriculture field to Design a reaper machine to harvest grains more efficiently. The research work focusing on harvesting operation to the small land holder to cutting varieties of crop in less time and at low cost by considering the factor as power requirement, ease of operation, field condition And Various mechanism of converting the rotating motion into sliding

motion such as slider crank mechanism, scotch yoke, cam and follower, rack and pinion etc.

Dr.U.V Kongre created a machine set up which is used to cut the crop with the helps of manpower pushing force which is provided with different sprocket, chain and bevel gear mechanism which results in transmissions of this manual motion into rotary motion. In this machine they uses a two circular saw blades, in which two bevel gear arrangement set up uses to converting the rotary motion of the wheel. These blades are fixed and limited to same distance so that small area of cutting generated.

Laukik P. Raut (2014) created a small scale harvester machine. The machine targets small scale farmers who have land area of less than 2 acres. This machine is compact and can cut up to two rows of soybean plant. It has cutting blades which cut the crop in a scissoring type of motion. It runs on diesel engine of 5HP, this power from engine, is provided through pulley and gear box arrangement to the cutter. A collecting mechanism is provided for the collection of crops to one side after cutting. The mechanism is powered by pulley arrangement. The compact harvester is manufactured using locally available spare parts and thus, it is easily maintainable

A.R.Bhabad (2017) fabricated a machine which is suitable for small scale farmers who have farm area of less than 2 acre. This reaper can cut 2 rows of maize stalk or bajra stalk upto 20cm width. It has high strength cutting blade which work on the scotch yoke mechanism. Scotch yoke mechanism converting the rotating motion in to the slider reciprocating motion. In this machine they uses the zig-zag blades and crop collecting system.

Habib (2001), mentioned that increasing plant diameter needs higher knife velocity for performing the free cutting operation. Whereas, increasing mass of plant stalks needs low critical speed. They added that critical knife velocity affected by both height of knife from the ground and the plant overall length. Also, moisture content of plants materials affecting on the critical knife velocity throwing by the cutting force, where the cutting force variation with the moisture content.

Mr. R. A. Ghumadwar (2016) presents the concept for design and analysis of crop cutter. The aim of this project is to design and analysis of small field crop cutter machine for small height crops. The machine consists of petrol engine to operate cutting roller and blade. When compare to manual crop cutting by and this machine has a capacity to cut the crop in faster. This machine is useful for both the small as well as big farm. The machine focuses to combination of cutting and collecting the crop for small scale farmers. In which the transmission of power to the cutter by using the belt drive to the roller cutter and cutting blade. The power transmitted engine to cutter shaft by using belt drive and pulley.

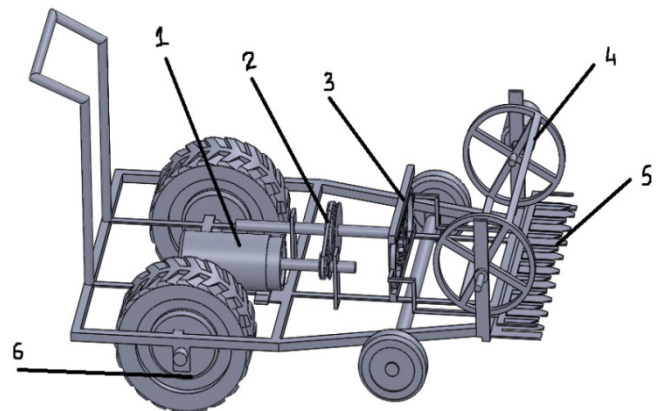
Ashish. M. Wankhade (2015) this project is based on developing a machine which focuses on labour problems faced by small scale farmers who have agricultural land. The machine developed can harvest up to two rows of soya bean plant at a time. The components of the machine comprise of a diesel engine of 3.5hp, pulley, a belt drive, a collecting mechanism and a cutter. The crop is being harvested by a scissoring type of motion. The power from the engine is provided to the cutter through pulley and belt arrangement. Powered by the pulley arrangement a collecting mechanism is being provided to the adjacent side of the cutter to collect the harvested crops. This machine is a simple and efficient solution to the problems faced by small scale farmers as it reduces the cost of harvesting to a considerable amount as compared to that of manual harvesting. The machine developed is small, compact and at very reasonable cost. Also, it is easy to maintain as it is made up of local spare parts which are easily available.

### 3. METHODOLOGY

The aim was to fabricate affordable crop cutting, collector machine for increasing the economy of small scale farmers. For the fulfillment of this aim, it is decided to follow following steps:

- 1) By Field survey: Interview the local farmers who have small scale land holding and farming the wheat. Find out problems in traditional machines.
- 2) Interview agricultural equipment manufacturers to get information about various types of mechanism used for cutting purpose such as, slider crank, Cam follower, Scotch yoke, Gear mechanism

- 3) Refer various international papers in small scale harvesters produced earlier.
- 4) Design of crop cutting machine.



**Fig. 1. 1) Motor, 2) Pulley transmission system, 3) Rack and pinion mechanism, 4) collecting system, 5) straight cutter blade, 6) wheels**

Past data bases like Google scholar, Google patents and relevant papers for small scale harvesters were examined. The purpose was to gain an insight into what researches have been done earlier and what were the implications of those designs.

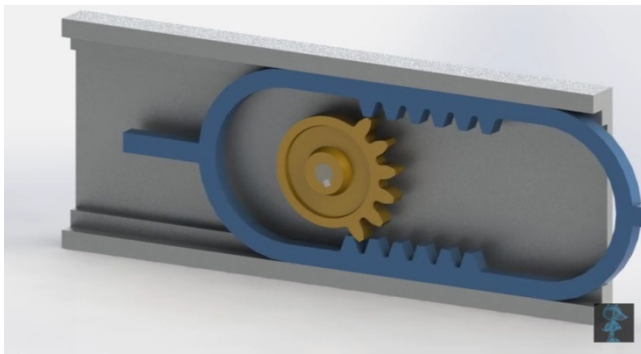
#### 3.1 Working

The machine is a walk behind type of harvester which is powered by the 3.5 HP, 3600 rpm engine. With the help of V- belt drive power is transmitted to cutter. The engine power is transmitted to cutter bar through belt pulley. One end of this output shaft is connected to rack and pinion mechanism which converts rotary motion of shaft into reciprocating motion of cutter blade. Cutter assembly consists of a sliding cutter plate and a stationery cutter plate. The cutters used are of straight shape. In sliding cutter plate, cutter blade is riveted with the rack and pinion arrangement and stationery cutter plate is riveted on the chassis. Reciprocating cutter blade slides over fixed blade and creates scissoring action responsible for cutting the crops.

Collecting mechanism consist of the cylindrical section which consist of three blades. The crops are guided towards backside by means of the cylindrical collecting system mounted in front of the cutting frame. During forward motion of the reaper, crop row dividers divide the crop which comes in contact with the cutter bar where shearing of crops stems takes place by means of the guiding plates and fix in to the star wheels so that while cutting it will not fall in front. After cutting the crop collecting cylinder simply takes inside and at the just back side of cutter there is a mechanism of pushing the crops into the sideway.

### 3.2 Double Rack and pinion Mechanism

A double rack and pinion arrangement is used for motion conversion between a rotating motion into a reciprocating motion, in which the motion conversion mechanism is constituted such that a reciprocator having racks along the opposite inner sides thereof is combined with a pinion having teeth along a part of the circumference thereof. When the reciprocator performs reciprocating motions, the teeth of the pinion are meshed with either one of the racks, thereby letting the pinion continuously revolve. In this at the time of half revolution one rack is being enmeshed with the pinion, so that in one complete revolution of pinion cutter gives both forward and back movement. The rack teeth fixed in the frame and the whole frame gives the reciprocating motion.



**Fig. 2. A schematic plan view of a motion conversion mechanism**

### 4. CONCLUSION

The present work was carried out with objective to design, Modification and evaluate the performance of wheat crop cutting machine .As compared with the different mechanism of crop cutting such as slider crank, cam follower and scotch yoke.

This proposed mechanism is more affective and reliable .it makes the cutting process faster. The machine can be operated by single operator, thus will eliminate the labor problem and struggle of labor in cutting the crop. A

complete 3D model of the crop cutting machine was developed using Solid edge modeling software to assess the design. The mechanism is still undergo in a detailed analysis and design of each components used.

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# Model Predictive Control for 3D Printers using State Space Modelling

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**Abstract:** The Model Predictive Control (MPC) has enticed many researchers' attention from last few decades because of its diversification in many technological fields. This paper provides review on how Model Predictive Control is contributing in Additive Manufacturing. In case of Additive Manufacturing assurance of quality of product can be achieved by use of Model Predictive Control (MPC) which is not possible in conventional way of determining quality after manufacturing. For that State space method is used as one of the methods to obtain state of system over given horizon of prediction. From this it will be able to determine pattern of operation of system for target product. This paper focuses on model based approach for study of Model Predictive Control In context of 3D printers.

**Keywords:** Model Predictive Control (MPC), State space Modelling, Prediction error.

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## 1. INTRODUCTION

Manufacturing processes are broadly classified into two types first one is known as subtractive manufacturing and another one is known as additive manufacturing. Later one is expanding its horizons and scopes day by day and becoming one of the most rapidly growing manufacturing technologies. The Additive Manufacturing can be defined as "process of joining materials to make objects from three-dimensional (3D) model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies". The widespread adoption of Additive Manufacturing (AM) (ASTM Standard 2792 2012) is challenged by part quality issues, such as dimensional and form errors, undesired porosity, delamination of layers, as well as poor or undefined material properties. Part quality issues can be attributed to the AM process parameter setting, typically done today by a trial-and-error method for each material. This involves post manufacturing analysis of product to determine whether product has achieved all of its target requirements. This process comes with many demerits such as increase in cost and waste of material. This kind of data yields very limited amount of improvements in product quality. Hence to overcome such problems there is need to implement Predictive Process Control in Additive Manufacturing.

Computational intelligence techniques such as artificial neural networks, fuzzy systems and genetic algorithms have been used for quality prediction in a variety of application but it has been found that there use in field of Additive Manufacturing is limited.

Control approaches that use embedded process models are generally classified as "model predictive".The general

philosophy underlying predictive control is that by embedding "process knowledge" into the controller, improved performance can be attained. The performance measure usually includes specifications about the process output across a time horizon, which may extend to steady state. The (mathematical) statement defining the performance measure determines essential controller characteristics. Depending on implementation details, it may also determine the controller "personality" in terms of specification and tuning parameters.

## 2. HISTORICAL BACKGROUND

MPC, arisen from industrial process control in 1970s, deals with control problems of constrained systems in the framework of optimization, which implies the study of constrained control developed from feedback stabilization to system optimization. It has been used for predicting future consequences on output of model due to present actions taken on the input of given model. The MPC concept has a long history. The connections between the closely related minimum time optimal control problem and Linear Programming were recognized first by Zadeh and Whalen (1962). Propoi (1963) proposed the moving horizon approach which is at the core of all MPC algorithms. It has been observed that MPC most predominantly used in chemical process industry. Also, it has been involved in number of applications such as super heaters, wind tunnel, utility boiler connected to distillation column and glass furnace etc. since year 1978. Now it has started to enter into mature phase by its diversification in many other technological fields.

Traditionally, two sets of industrial applications are accepted as marking the beginning of predictive control.

Model algorithmic control (MAC) also known as IDCOM, IDentification and COMmand and dynamic matrix control, DMC. Now it has started to enter into mature phase by its diversification in many other technological fields. 3D printing is still considered as nascent area of application for Model Predictive Control as use of MPC is not often observed in 3D printing systems.

### 3. MODEL PREDICTIVE CONTROL(MPC)

Model Predictive control(MPC) has been developed considerably both in industry and academia, this success is due to the fact that model predictive control is perhaps most general way of posing control problem in time domain.

Model predictive Control can provide forecasting of printing process dynamics which has several advantages:

#### 3.1.Improvement in quality:

Definition of quality as per ISO 9000.

"The degree to which a set of inherent characteristics fulfils requirements"

- Quality can be used with adjectives such as poor, good, excellent...
- 'Inherent', as opposed to 'assigned
- "means existing in something, especially as a permanent characteristic... Requirement': A need or expectation that is stated, generally implied
- or obligatory Stated
- means usually explicitly in a document. Generally implied
- means that it is custom or common practice for the organization, its customers and other interested parties. Requirement is the expression in the content of a document conveying criteria to be fulfilled if compliance with the document is to be claimed and from which no deviation is permitted.

With help of Model Predictive Control it is possible predict capability of 3D printing system which can help to enhance performance of that system for stipulated process. That can provide a cutting edge for improvement in quality.

#### 3.2.Dimensional accuracy:

Due to prediction of quality in advance it becomes always sophisticated to maintain dimensional accuracy. Also from use of MPC it becomes possible to judge capability of different additive manufacturing techniques which can be conducive to select Additive Manufacturing processes on basis of comparison between quality capability of different processes.

#### 3.3. Material optimization:

Defects in manufacturing generally involve two types of major problems. One is additional material than required

and second is less material than requirement. This can be solved either by removing material in first case or by directly sending product to scrap in second case. MPC enables use of exact material as it is required for manufacturing particular product which can be very difficult to predict in case of conventional way.

#### 3.4.Reduction in time of manufacturing and post processing quality check:

The manufacturing of product in Additive Manufacturing is mainly classified into three phases. First phase is actual manufacturing, second one involves post processing, third one involves quality check. MPC can be helpful to reduce time required for quality check as quality is already determined from system's model based study.

#### 3.5.Cost Reduction:

Cost is considered as function of time and material. As MPC reduces total time required for manufacturing and material requirement it results in reduction of cost of manufacturing any product.

### 4. STATE SPACE MODELLING OF MODEL PREDICTIVE CONTROL

This involves two stages as follows:

1. State space model Identification.
2. MPC using state space modelling.

#### 4.1. State space Model Identification:

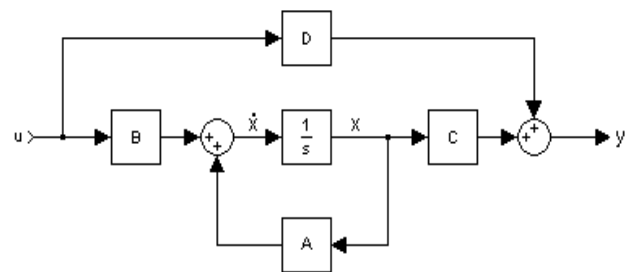


Fig. 1. State space model

State space modelling is very important in order to determine state of system on basis of state equation and output equation. In control theory nth order differential equation can be decomposed into n number of first order differential equations, this first order differential equation is known as state space equation.

$$u(t) = D^n y(t) + D^{n-1} y(t) a_{n-1} + \dots + y(t) a_0.$$

where,

$u(t)$  = Input to system.

$y(t)$  = Output to system.

$$D = \frac{dy(t)}{dt}$$

This is the nth order differential equation which represents system which is used to convert input  $x(t)$  into output  $y(t)$ . State of system refers to past, present and future conditions of systems. To define state of system there is need to define state variables.

The first order equation which relates input and state variables is known as state equation and the equation which gives correlation between output and state variables is known as output equation in state space modelling.

As in this case model based approach has been adopted there is need to identify parameters which plays an important role in relation with state. Let  $\theta$  represent parameters. For understanding model based approach there is need to define these parameters with help of vector. Hence  $P(\theta)$  is parameters vector which consist of superset of all parameters which are affecting on model of system (3D printers) that we are going to consider. In Matrix form it can be represented as:

$$P(\theta)=[\theta_1, \theta_2, \theta_3, \dots, \theta_n].$$

Now state equation for the system can be given for time horizon of  $t+1$  as follows:

$$\begin{aligned} x(t+1) &= A(\theta)x(t) + B(\theta)u(t) \\ &+ k(\theta)e(t) \end{aligned} \quad \dots \quad (i)$$

As per the definition of state equation it can be interpreted as:

$$\text{State of system} = \text{State variable} + \text{input variable} + \text{External disturbance} \quad \dots(ii)$$

From equations (i) and (ii)

$$x(t+1) = \text{State of system}.$$

$$A(\theta)x(t) = \text{State Variable}.$$

$$B(\theta)u(t) = \text{Input Variable}.$$

$$k(\theta)e(t) = \text{External Disturbance}.$$

Now for the given system output equation can be given as:

$$\begin{aligned} y(t) &= C(\theta)x(t) \\ &+ e(t) \end{aligned} \quad \dots \quad (iii)$$

As per the definition of output equation:

$$\text{Output} = \text{State of system} + \text{External Disturbance} \dots(iv)$$

From equations (iii) and (iv)

$$y(t) = \text{Measured Output}$$

$$C(\theta)x(t) = \text{state of system}$$

$$e(t) = \text{External Disturbance}$$

This modelling provides us with Measured output of 3D printing system which is given by equation (iii). Now for achieving exact prediction about output of system there is need to reduce prediction error. Prediction error is defined as difference between predicted output and measured output represented by following equation.

$$\begin{aligned} \text{Prediction Error} &= \text{Measured Output} \\ &- \text{Predicted Output} \end{aligned} \quad \dots (v)$$

From equation (iii) Measured output consist of the state of system and external disturbance but it is not possible to find out amount of external disturbance in predicted output hence, predicted output will be only consisting of state of system.

$$\begin{aligned} \text{Predicted Output} &= C(\theta)x(t) \end{aligned} \quad \dots (vi)$$

From equations (v) and (vi)

$$\begin{aligned} \text{Prediction error} &= y(t) - C(\theta)x(t) \end{aligned} \quad \dots (vii)$$

Hence for identifying state space modelling that means exact output from 3D printing system for given horizon of time and parameters there is need to minimize prediction error. The prediction error is function of input parameter ( $\theta$ ), time ( $t$ ). Hence for minimizing prediction error there is need to minimize either number of input parameters or time horizon or both which results in exact identification of state space model.

#### 4.2.MPC using state space Modelling:

This phase involves considering particular time step. Let  $k$  be that time step for applying MPC. There is need of sampling for achieving accurate prediction over time step of  $k$ . For minimizing prediction error there is need to manipulate input variable parameters. Due to this variation in parameters there will be variation in output. This is represented by following equation:

$$\begin{aligned} \Delta u(t) &= y'(t) \end{aligned} \quad \dots (viii)$$

For time horizon ( $t$ ) there will be time step  $k$ , which leads to convert equation (viii) into equation (ix)

$$\Delta u(k) = y'(k) \dots \quad (ix)$$

Where,

$$\begin{aligned} \Delta u(k) &= \text{Change in input for time step } k. \\ y'(k) &= \text{change in output.} \end{aligned}$$

This change in output produces output trajectory. The output trajectory is given by trajectory function  $T(k)$ .

For achieving MPC there is need to minimize trajectory  $T(k)$  which will result in reduction of error function. The error function is depending upon two variables  $\Delta u(k)$  and  $k$ .

$$\text{ErrorFunctionforMPC} = J(\Delta u(k), k) = \| y'(k) - T(k) \|^2 + Q \| \Delta u(k) \|^2 \quad \dots(x)$$

From equation (x) there is need to minimize  $\Delta u(k)$  which leads to optimization function  $\Delta * u(k)$  which is found analytically. For controlling value for step  $k$  following equation is used:

$$\begin{aligned} u(k) \\ = u(k-1) + \Delta \\ * u(k) \end{aligned} \quad \dots(xi)$$

## 5. CONCLUSIONS

MPC can be useful in order to achieve Additive manufacturing capabilities such as design flexibility, less cost of geometric complexity, dimensional accuracy, time and cost- efficient production etc. with enhanced efficiency. Also, MPC can be useful in achieving better surface roughness and resolution of printing. This is possible because of minimization of prediction error. With help of state space modelling it is possible to design robust system which can provide exactly targeted output from selected 3D printer system.

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# Design of a Solar Updraft Tower with all the Variable Geometric Parameter

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**Abstract:** Fossil fuel prices will continue to rise, as resources are limited and demand is rising rapidly. Solar Updraft Towers today are already directly competitive with oil-fired power plants. Due to rising costs for all fossil fuels including natural gas, they will soon be also competitive with natural gas fired combined cycle plants. The need for carbon-free environmentally benign power generation technologies will further boost the demand for solar power plants. A possible solution to the ever-increasing problem is solar energy. It is an abundant, renewable source of energy that only needs to be harnessed to be of use to man. Solar power plants in use in the world are equipped to transform solar radiation into electrical energy via any one of a number of cycles or natural phenomena. The present study is undertaken to design a solar updraft tower with all the variable geometric parameter

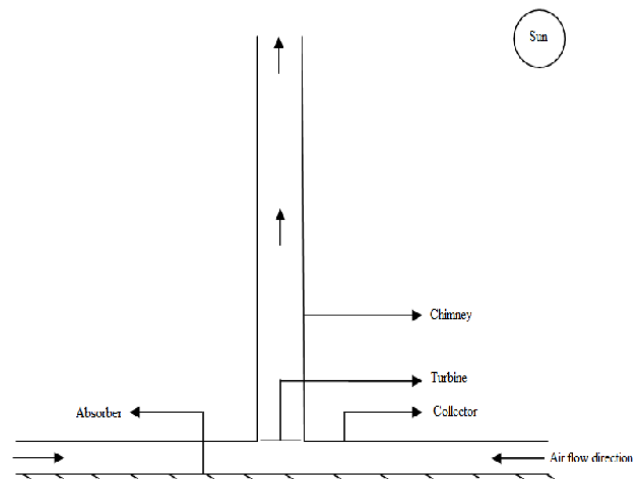
**Keywords-** Solar energy, updraft towers, chimney, collector, wind Turbine, solar Radiations, wind

## 1. INTRODUCTION

The Solar Chimney operates like a hydroelectric power plant, but instead of water, it uses hot air this is particularly useful in arid areas. The solar chimney power plant system consists of four major components—collector, chimney, energy storage layer and one or more turbo generators at the base. Air underneath the low circular transparent glass open at the circumference is heated by radiation from the sun. The chimney, a vertical tower tube with large air inlets at its base, stands in the centre of the collector. The joint between the collector and the chimney is airtight. The wind turbine is installed at the bottom of the chimney for the large-scale solar chimney system; there may be several wind turbines inside as it is difficult, at the current time, to produce wind turbines with rated load over 10MW. The model works on the principle that in the collector, solar radiation is used to heat an absorber (ordinarily soil or water bags) on the ground, and then a large body of air is heated by convection currents as the density of hot air inside the system is less than that of the cold air in the environment at the same height, the hot air is forced by the buoyancy to move up the chimney as a hot wind which acts as a driving force by this suction effect it flows through either one large turbine or numerous smaller turbines. The energy of the air flow is converted into mechanical energy at the base of the tower, and ultimately into electrical energy by electric generators.

This paper proposes design parameters involved in the solar updraft tower. Based on these parameters i.e independent and dependent variables of involved in the design of experimental setup of solar updraft tower, correlation can be formed between independent and dependent variables. This correlation formed between input and output variables

is the mathematical model. The performance of the solar updraft can be predicated based on the mathematical model and accordingly design can be optimized.



**Fig. 1. Schematic Illustration of a Solar Chimney Power Plant**

## 2. EXPERIMENTAL MODEL

The solar updraft tower is a renewable-energy power plant for generating electricity from solar power. Sunshine heats the air beneath a very wide greenhouse-like roofed collector structure surrounding the central base of a very tall chimney tower. The resulting convection causes a hot air updraft in the tower by the chimney effect. This airflow drives wind turbines placed in the chimney updraft or around the chimney base to produce electricity. Power output depends primarily on two factors: collector area and chimney height.



A larger area collects and warms a greater volume of air to flow up the chimney; Turbines with a vertical axis can be installed in a ring around the base of the tower.



**Fig 2: Experimental setup of solar updraft tower**

### 3. MODEL FORMULATION

The response of any phenomenon in terms of proper interaction of various inputs of the phenomenon has been proposed in the present investigation which involves following steps

- i. Identification of variables or parameter affecting the phenomenon
- ii. Reduction of variables through dimensionless analysis
- iii. Test planning
- iv. Rejection of absurd data
- v. Formulation of model

#### 3.1 Identification of variables

It is to be done based on known qualitative physics of the phenomenon. These variables are of three types

- 1) Independent variables
- 2) Dependent variables
- 3) Extraneous variables

The term variable is used in a general sense to imply any physical quantity that undergoes change. Any aspect or a physical quantity, due to variation in it, which influences the final outcome of an activity or a phenomenon are known as input or independent variable of the activity. If a physical quantity can be changed independent of other quantities, then, it is also an independent variable. If a physical quantity can be changes in response to the variation of one or more number of variables, then it is termed as dependent or response variable. If a physical quantity that affects our test is changing in random and in uncontrolled manner in the phenomenon, then it is called as an extraneous variable.

#### 3.2 Identify the Causes and Effects

Performing Qualitative analysis of physics of such a phenomenon and establishing Dimensional equation for such a phenomenon. Once the Dimensional equation is formed, it is a confirmation that all involved physical quantities have been considered. Evolving the Dimensionless Input quantities due to physical quantities is the first step in this direction. These are the Causes (Inputs).

#### 3.3 Physical design of an Experimental set up

Here, it is necessary to workout physical design of an experimental set up including deciding specifications and procurement of Instrumentation. Subsequently, these are necessary to be set-up.

Next step would be to execute experimentation as per test planning and gather data regarding Causes (Inputs) and Effects (Responses). Finally, we establish the relationship between Outputs (Effects) and Inputs (Causes).

#### 3.4 Independent and Dependent Variables of Solar Tower

The solar updraft tower activity is influenced by following variables.

**TABLE 1: Independent and dependent variable-solar updraft tower**

S.N	Description of Variables	Type of variable	Symbol	Unit
1	Power Output	Dependent	Po	KW
2	Efficiency	Dependent	E	%
3	Collector height	Independent	Ch	m
4	Collector radius	Independent	Cr	m
5	Gravitational Constant	Independent	g	m/s ²
6	Collector pressure loss Coefficient	Independent	Clc	--
7	Specific Heat	Independent	Cv	M2/KS2
8	Ratio of absorbed solar energy	Independent	αs	--
9	Collector heat transfer coefficient	Independent	αco	W/m2K
10	Collector Temperature	Independent	Tco	K
11	Solar power per surface area	Independent	Qs	W/m2s
12	Solar profile	Independent	α	--
13	Solar radiation Energy	Independent	Sre	W/m2
14	Wind speed	Independent	Ws	m/s
15	Chimney Height	Independent	chH	m
16	Chimney Radius	Independent	chR	m
17	Chimney Volume	Independent	chV	m3
18	Chimney pressure	Independent	Chc	--

S.N	Description of Variables	Type of variable	Symbol	Unit
	loss Coefficient			
19	Chimney heat transfer coefficient	Independent	$\alpha_{ch}$	W/m ² K
20	Chimney Temperature	Independent	Tch	K
21	Chimney Weight	Independent	ChW	Kg
22	Pressure difference	Independent	$\Delta p$	N/m ²
23	No. of Turbines Blades	Independent	Nt	--
24	Turbine Blade Profile	Independent	Bp	--
25	Blade Tip Speed	Independent	Bs	m/s
26	Collector Thickness	Independent	Cth	m
27	Roof Height	Independent	Rh	m

### 3.5 Establishment of Dimensionless Pi Terms

The independent variables have been reduced into a group of pi terms using Buckingham's Pi Theorem. The equation 1 ahead shows the relationships of dimensionless pi terms of the phenomenon. The probable exact mathematical form for dimensional equation of the phenomenon could be relationships assumed to be of exponential form

$$Po = K * [(\pi \text{ terms related to Collector Parameters})]^a [(\pi \text{ terms related to Chimney Parameters})]^b [(\pi \text{ terms related to turbine})]^c [(\pi \text{ terms related to wind speed})]^d [(\pi \text{ terms related to solar radiation})]^e$$

Eq (1)

### 3.6 Model Formulation by Identifying The Curve Fitting Constant And Various Indices of Pi Terms of Solar Tower

The multiple regression analysis helps to identify the indices of the different pi terms in the model aimed at, by considering five independent pi terms and one dependent pi term. Let model aimed at be of the form

$$z_1 = k_1 [(\pi_1)^{a_1} * (\pi_2)^{b_1} * (\pi_3)^{c_1} * (\pi_4)^{d_1} * (\pi_5)^{e_1}]$$

Eq (2)

This is known as exponential form of model

In above equations (2 and 3), dependent variables  $z_1$  represents power output of solar tower and  $z_2$  represents efficiency of solar updraft tower. Independent variables  $\pi_1$  represents collector data,  $\pi_2$  represents chimney data,  $\pi_3$  represents turbine data,  $\pi_4$  represents wind speed and  $\pi_5$  represents solar radiation. To determine the values of  $a_1$ ,  $a_1$ ,  $b_1$ ,  $c_1$ ,  $d_1$  and  $e_1$  to arrive at the regression hyper plane, the above equations are presented as follows.

Taking log on the both sides of equation 2 for power output of solar tower(  $z_1$ ) we get six unknown terms in the equations,

$$\log z_1 = \log k_1 + a_1 \log \pi_1 + b_1 \log \pi_2 + c_1 \log \pi_3 + d_1 \log \pi_4 + e_1 \log \pi_5$$

$$\text{Let, } Z_1 = \log z_1, \quad K_1 = \log k_1, \quad A = \log \pi_1, \quad B = \log \pi_2, \quad C = \log \pi_3, \quad D = \log \pi_4, \quad E = \log \pi_5$$

Putting these values in log equation 5 the same can be written as

$$Z_1 = K_1 + a_1 A + b_1 B + c_1 C + d_1 D + e_1 E$$

This is a regression equations of Z on A, B, C, D, E in an n dimensional coordinate system this represents a regression hyper plane as

The regression equations become as under

$$\sum z_1 = n K_1 + a_1 \sum A + b_1 \sum B + c_1 \sum C + d_1 \sum D + e_1 \sum E$$

$$\sum z_1 A = K_1 \sum A + a_1 \sum A^2 + b_1 \sum AB + c_1 \sum AC + d_1 \sum AD + e_1 \sum AE$$

$$\sum z_1 B = K_1 \sum B + a_1 \sum AB + b_1 \sum B^2 + c_1 \sum BC + d_1 \sum BD + e_1 \sum BE$$

$$\sum z_1 C = K_1 \sum C + a_1 \sum AC + b_1 \sum BC + c_1 \sum C^2 + d_1 \sum CD + e_1 \sum CE$$

$$\sum z_1 D = K_1 \sum D + a_1 \sum AD + b_1 \sum BD + c_1 \sum CD + d_1 \sum D^2 + e_1 \sum DE$$

$$\sum z_1 E = K_1 \sum E + a_1 \sum AE + b_1 \sum BE + c_1 \sum CE + d_1 \sum DE + e_1 \sum E^2$$

$$\sum z_1 K = K_1 \sum K + a_1 \sum AK + b_1 \sum BK + c_1 \sum CK + d_1 \sum DK + e_1 \sum EK$$

Eq (5)

In the above equations, n is the number of sets of readings and A, B, C, D and E represent the independent pi terms  $\pi_1$ ,  $\pi_2$ ,  $\pi_3$ ,  $\pi_4$  and  $\pi_5$  While, Z represents, dependent pi term. Next, calculate the values of independent pi terms for corresponding dependent pi term, which helps to form the equations in the matrix form.

$$[Z] = [W] * [X]$$

The matrix method of solving these equations using 'MATLAB' is given below.

W = 6x6 matrix of the multipliers of  $K_1$ ,  $a_1$ ,  $b_1$ ,  $c_1$ ,  $d_1$  and  $e_1$

Z = 6x1 matrix of the terms on L H S and

X = 6x1 matrix of solutions of values of  $K_1$ ,  $a_1$ ,  $b_1$ ,  $c_1$ ,  $d_1$  and  $e_1$

Then, the matrix obtained is given by,

Matrix

$$\begin{bmatrix} 1 \\ A \\ B \\ C \\ D \\ E \end{bmatrix} = \begin{bmatrix} n & A & B & C & D & E \\ A & A^2 & BA & CA & DA & EA \\ B & AB & B^2 & CB & DB & EB \\ C & AC & BC & C^2 & DC & EC \\ D & AD & BD & CD & D^2 & ED \\ E & AE & BE & CE & DE & E^2 \end{bmatrix} \times \begin{bmatrix} K_1 \\ a_1 \\ b_1 \\ c_1 \\ d_1 \\ e_1 \end{bmatrix}$$

X1 matrix with  $K_1$  and indices  $a_1$ ,  $b_1$ ,  $c_1$ ,  $d_1$  and  $e_1$  evaluated:

Solving, the above matrix by using MATLAB software, the values of constant and different indices of the proposed model have been found out.

#### 4. MODELS DEVELOPED (PROPOSE) FOR DEPENDENT VARIABLES OF TOWER.

The exact forms of models for dependent variables, of solar updraft tower are as under.

$$Po = (z1) = k1 * [(\pi1)^{a1} * (\pi2)^{b1} * (\pi3)^{c1} * (\pi4)^{d1} * (\pi5)^{e1}] \quad \text{Eq (5)}$$

$$E = (z2) = k2 * [(\pi1)^{a2} * (\pi2)^{b2} * (\pi3)^{c2} * (\pi4)^{d2} * (\pi5)^{e2}] \quad \text{Eq (6)}$$

In the above equations (z1) is relating to response variable for power output of solar tower and (z2) is relating to response efficiency of solar tower.

#### 5. RESULTS

The indices of the models of solar updraft tower are the indicators of how the phenomenon is getting affected because of the interaction of various independent pi terms in model. Interpretation of model is being reported in terms of several aspects viz. interpretation of curve fitting constant k, order of influence of various inputs (causes) on outputs (effects), relative influence of causes and effect.

#### 6. CONCLUSIONS

The value of curve fitting constant k1 in z1 and k2 in z2 collectively represents the combined effect of all extraneous variables. Further, as it is positive, this indicates that, there are good numbers of causes, which have increasing influence on power output of solar updraft tower z1 and Solar updraft tower efficiency z2.

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# Virtual Manufacturing: A New Trend in Technology

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**Abstract:** In this paper, Virtual Manufacturing: A New Trend in Technology, an attempt is made to give an idea about existing scenario about virtual manufacturing techniques. Also, further innovations creating an integrated environment which results in improvised manufacturing process and other domains such as machine tools, virtual methods/techniques, software applications and market effects are highlighted. Impact of this technology on economic level, industrial level, geographical space and new innovative methodology and application such as virtual prototyping, virtual manufacturing, virtual reality and virtual factory are discussed.

**Keywords:** Virtual Manufacturing, Machine Tools, Software Applications.

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## 1. INTRODUCTION

Shailendra, Prakash and Vivek (2015) discussed that Virtual Manufacturing makes use of 3D technology which helps designer to create object or designs according to his specified parameters virtually. This user friendly platform helps to study more about object specification like length, width, material used. This interface provides us opportunity to upgrade and modify specifications and other parameters every easily without any loss of money. Hence, it is cost effective and time effective. Virtual Manufacturing (VM) is a new and beneficial kind of existing manufacturing technology, further researches are done to improve it. It can be used for modeling based on simulation technology, information technology and virtual reality technology. This above process can boost the manufacturing process with many parallel operations going on, which also affects the design of the production. It apparently gives us feel of model virtually before it actually comes into existence. Due to which it makes very economical, feasible for all manufacturing units owned by production unit. The proper analysis of model to be developed and proper testing which is to be done virtually helps in minimization of cost and we get more improvised quality which results in optimized efficiency of production. Software for Computer-Aided Design (CAD), Computer Aided Manufacturing (CAM), Design for Assembly (DFA), Design for Manufacture (DFM) and ANSYS have been very beneficial even, Integrated CAD/CAM, solid modelling, parametric design and feature recognition are all valuable tools that have been developed for these software products. So the above concept is discussed in . This integration has helped designers to design a product on a platform where everyone can edit it and even it can be transferred the model in various software applications instead of recreating it. Demands related to modern manufacturing process are still not properly fulfilled and hence newer technology has been invented to ease the working for engineers. Today the most advanced

form of CAD is Virtual Manufacturing which includes concept of virtual reality. Concept of this artificial reality already existed in 1970 and it was first introduced by Jaron Lanier in 1989. In 1990, virtual world and virtual environment were defined. In short, virtual reality can be termed as computer generated 3D environment which is interactive and depicts reality. Last three decades marked remarkable research in virtual reality they are as follows (J.N Marcincin, 2001):

- Sensorama - Morton Heilig created a multi-sensory simulator. A film which was prerecorded in color and effects such as binaural sounds, smell, air and vibration experiences were given to it, also featured surrounding environment but was not interactive.
- The Ultimate Display – in 1965 Ivan Sutherland initiated the idea of artificial world construction concept. It had interactive graphics, force sensation, sound, taste, smell.
- “The Sword of Damocles” - It was the first virtual reality concept embedded in hardware. Ivan Sutherland constructs a device considered as the first Head Mounted display (HMD), it had head tracking. View was changed according to head's alignment and orientation.
- GROPE - the first prototype of a force-feedback system founded at the University of North Carolina (UNC) in 1971.
- VIDEOPLACE - Artificial Reality which was created in 1975 by Myron Krueger - “a conceptual environment, with no existence”. The clips captured by camera were projected on large screen and users were able to communicate with each other through image processing techniques in 2D.

- VCASS - Thomas Furness at the US Air Force's Armstrong Medical Research Laboratories invented the Visually Coupled Airborne Systems Simulator in 1982. The fighter pilot wore a HMD that enhanced the view outside for direction and targets.
- VIVED - Virtual Visual Environment Display – constructed at the NASA Ames in 1984, it was a stereoscopic monochrome.
- VPL - The VPL Company manufactures the popular Data- Glove (1985) and the Eye phone HMD (1988) - the first VR devices.
- BOOM - Fake Space Labs in 1989 discovered BOOM which is a small box containing two CRT monitors that can be viewed through the eye holes. The user grabs the box, and the mechanical arm measures the position and orientation of the box.
- UNC Walkthrough project - in the second half of 1980s at the University of North Carolina an architectural walkthrough application was developed.
- Virtual Wind Tunnel - developed in early 1990s at the NASA Ames which allows observation of flow field by using BOOM and Data Glove.
- CAVE - In 1992 CAVE (CAVE Automatic Virtual Environment) is a scientific visualization system. It projects images on the walls of room (user should wear LCD shutter glasses). Both quality and resolution of viewed images, and field of view is better as compared to HMD systems
- Augmented Reality (AR) - a technology that “presents a virtual world that enhances, instead of replacing the reality. It became very important from research point of view. This works by means of see-through HMD that merges virtual three-dimensional objects on real figures.

Virtual Manufacturing got its existence in early 1990, it has gained wide international acceptance when initiated by Defense department of U.S. Earlier its scope was very limited but recently due to improvised version of software's and hardware's this technology is accepted worldwide. Virtual manufacturing includes the fast improvement of manufacturing processes without drawing on the machines' operating time fund. It is said that Virtual Manufacturing is the use of a desktop virtual reality system for the computer-aided design of components and processes for manufacture (Prashant and Dan, 2011, p.320).

## 2. LITERATURE OVERVIEW

Following the successful application of this technology, a special issue of the journal on Virtual Manufacturing was organized at VIRMAN –an International Workshop on Virtual Manufacturing in 2006, 2007. At this meet up

various researchers discussed the result of their work in this field. They compared between physical and virtual manufacturing and focused the development made due to it, even negative aspects were put forth. Conclusion was many firms have accepted this technology but surely there is greater scope of expansion in implementation ways and evaluation techniques. Recent renaissance includes applications in state of art and state of practice in virtual reality and construction systems applied and evaluated. As a consequence of this, the sphere of this special issue has been expanded to include applications in state-of-the art and the state-of-the-practice virtual reality manufacturing and virtual construction systems. Melissa and Victor (1999) stated that Impact of VM is such that it almost affects market situation as well as its relation with customers and service provider until virtual reality and prototyping was taken into consideration and Specifically the impact is on sectors such as the company memory, capital investment, design of production; cost estimation, risk management, client interfaces, functionality interfaces, workshop. Hence the needs mentioned were:

- 1) Technology and Development for models and simulations.
- 2) Virtual Infrastructures.
- 3) Tools for working in the virtual spaces such as, for example, the CAD kernel.

Although the scope of VM covers manufacturing to company area so in order to set up proper technical approach of above phenomena two cases were proposed: CAD and Virtual Prototyping. Both will advance more in the area of the workshop. As defined by Callet (1997) from “the virtualization of the real to the realization of the virtual “which explains the new productive reality.

## 3. METHODOLOGY

According to technical report by Lawrence Associates Inc. (1994), Technical report, Modelling and Stimulation are two basic steps which includes what exactly to design on the basis of need and the presentation of model in relation with real system with accuracy and precision, respectively. Virtual Manufacturing can be further bifurcated into four different categories core, enabling, showstopper and common which means fundamental, necessary, mostly required, widely used, respectively. According to existing system this technology is implemented by given method:

1. Manufacturing Analyzation: Studies factors affecting model.
2. Model Representation: information is presented in such a way that it can be easily shared among all the application.
3. Virtual Visualization: representation in such a way that it seems almost real.

4. Verification
5. Multi discipline optimization: Various traditional methods are used to execute the process.

As mentioned above, Virtual Manufacturing (VM) process is generally implemented in this way .It can me improvised more by focusing on certain parameters which will result in time consuming or fast process of manufacturing. Hence, following steps can be followed to improve the manufacturing process:

1. Designing- Which is the most common basic step, here optimization of design and process must be done to achieve certain manufacturing goals (quality, flexibility, DFA) .It is recommended to make changes in design and production field, at this stage.
2. 3D modelling – focus should be made on its physical parameters as per needs. This activity must be completed in much less time.
3. Stress Analysis-This step must be production centered .Integrated Product Process Development (IPPD) must be used here to optimize the manufacturing process, analytical production in order to permit higher accuracy and acceptance
4. Rapid Prototyping-This step is control centered which controls whole manufacturing process. Additive Layer Manufacturing must be used which creates scale model part. Hence, analysis and observation of model becomes easy .Changes can be made by observing the scale model before giving command of mass production
5. 3D Printing- It is basically miniature representation of model which is manufactured according to inputs and hence it helps in further advanced changes.

#### 4. RESULT

According R. Radharamanan ( 2002), The existing VM technology can be used in Machine and Design such as - Computer Aided Engineering (CAE), 3-Dimensional Computer Aided Design (CAD) Models, and Design for Manufacturability & Assembly (DFMA). ·Production Tools - Computer Integrated Manufacturing (CIM), Advanced Modeling and Simulation, Distributed Interactive Simulation (DIS), Integrated Product/Process Development (IPPD), Just in Time (JIT), Materials Requirement Planning (MRP), Manufacturing Resources Planning (MRP II), Kanban, Virtual Reality, Visualization/ Animation Tools, Hybrid System Theory, Complexity Theory, Distributed Computing, and Self-Directed Control. ·Quality Tools - Total Quality Management (TQM), Quality Function Deployment (QFD). Also, it is implemented in Production tools, Automobile, Aerospace field.

The result based on improvised methodology can be mentioned as follows:

1. Flexible Manufacturing
2. Lean Manufacturing
3. Virtual Prototyping
4. Virtual Reality
5. Virtual Quality
6. Agile Manufacturing

Another important application of VM is Virtual Factory which manufactures design of different tool design, geometrical models and facilities in order to make component needed for any manufacturing process. Even, the design can be modified and updated according to factory need and hence implementing it into real factory. Hence this innovative framework saves time as well as cost irrespective of complex needs and hence improves life cycle of factory. Another very important need is to bring flexibility, reactance in order to stay competent and active in market. This is achieved by increasing quality and proper coordination of various internal and external. So, we must always try to update the structural design and requirements and with this concept we can deal with issues related to higher order production and demands related to adaptability, cost, efficiency, durability, reliability, scalability and security (Pedrazzoli et al., 2007).

#### 4.1 User Sector

(According to scenario of machine tool industry) he user sector of this virtually manufactured machine tools includes Automobiles and Auto ancillaries, Railways, Defense, Agriculture, Steel, fertilizers, Electrical, Electronics Telecommunication, textile machinery, Ball 25 & roller bearings, Industrial valves, Power driven pumps, Multi product engineering companies, Earth moving machinery, Compressors and consumer durables like washing machines, refrigerators, television sets, watches, vacuum cleaners, air conditioners, etc. Machine tools are also used for defense sector of our country like aero plane, war ship, nuclear power and various research organization which makes use of this concept.

#### 4.2 Prototyping VM

This aspect of manufacturing helps in electronics and telecommunication sector. Usually it deals with interface design, modelling and product design, manufacturing and sales. Instead of using physical prototype more use of virtual prototype is done for innovation, quality check and testing specific design or model. The following aspects are dominant (Melissa and Victor 1999):

- a) Functionality: product functionality and dynamic behavior

- b) Human Interaction: that is the platform must be user friendly
- c) Environment: combination of computer (non-real-time) and hardware-in-the-loop (real-time) can be performed.

#### 4.3 Socio-Economic Effect

VM provides enough confidence amongst the firm that they can deliver quality products to market or customer on specified time and cost. It reduces material wastage, tool cost, saves time which was invested in inspection. Overall, and it reduces manufacturing cost in production.

It also has impact on quality, shorter cycle time, producibility, interaction with customers i.e. customer relation, flexibility. This results are not implemented everywhere, some of them are still under development.

#### 5. CONCLUSION

As a conclusion of this paper, we can say that virtual manufacturing is a powerful element in reduction of risk factor included in manufacturing and development of new model also it is boon for various manufacturing units. Present situation gives us idea of impact of this technology and it can be predicted that overall efficiency, accuracy and quality can be enhanced. Even the concept of Rapid Prototyping is emerging which can change the era of manufacturing. As leading firms needs assured solution for faster production and to save cost, time. Already, successful demonstration of virtual manufacturing techniques are observed. Although, we lack proper integration of VM techniques. Newer invented techniques must be applied starting at unit level, then at sublevel and finally at system level. The scope of this technology can be extended in other production domain like marketing, service, sales. It has one major drawback that is, it is not affordable for small scale manufacturing.

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# Preparation and Study of Natural Rubber Nanocomposites with Zirconia Nanoparticles

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**Abstract:** The field of nanotechnology is one of the most popular areas of current research and development in all technical disciplines. The concept of enhancing the properties and applicability of the materials through nanophase reinforcement in an organic or inorganic matrix is not new for human civilization. The synthesis of polymer nanocomposites is an integral aspect of polymer nanotechnology. By inserting the nanometric inorganic compounds, the properties of polymers improve and hence this has a lot of applications depending upon the inorganic material present in the polymers. In this work we make a composite of Natural Rubber (NR) with Zirconium Oxide by compounding with Two Roll Mill, to improve and enhance the property of the rubber. Zirconium Oxide is prepared in lab by Solution gelation (Sol-gel) process. Characterization of Natural Rubber and Zirconium Oxide Nano composite is done by various tests. Structural characteristics of the NR nanocomposite and modification in the mechanical properties of the composite are observed by comparison. Surface morphology, Microstructural details, composition and surface structure are observed. Stress strain studies are found to be useful to assess the improvement of the mechanical properties of the composite. Scope and Application of Nanocomposites are discussed in accordance with current requirements.

**Keywords:** Natural Rubber, Zirconia Nanoparticles, Sol-Gel, Two Roll Mill

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## 1. INTRODUCTION

Acrylo Nitrile Butadiene Rubber (NBR) is a workhorse of the several industrial applications especially for automotive rubber products and in hydraulic area. Enhanced tribological properties of NBR are one of the crucial requirements for sealing applications (Agrawal, et al.). Natural rubber is one of the most important economic products. Because it can comfortably improve the properties with the addition of an appropriate amount of fillers to benefit the application concerned, it is widely used in various applications such as medical glove and tubing. Polymer nanocomposites as only small amount of the nanometer size filler dispersed inside the polymer exhibit markedly improved properties compared to the original or their traditional composites. They represent an alternative and a powerful technique to improve various polymer properties including increased modulus and strength, outstanding barrier properties, improved solvent and heat resistance and decreased flammability (Promdsorn, et al.). Research of newer materials with effective tribological characteristic is demand of all transportation industries, power generation sector and manufacturing area for higher efficiency and environmental protection. One common example is a passenger car uses one third of its fuel energy to overcome friction in the engine transmission, tires and brakes. Around the globe concerted efforts are continued in developing lubricants, new materials, and coatings that can lower the friction and wear parameters potentially even under severe operating conditions. With the development of

nanotechnology, the Nano form of materials are in superior demand (Agrawal, et al.).

Although there are several new synthetic rubbers which have been developed to meet more demanding requirements, natural rubber (NR) still dominates nearly half of the total rubber consumption worldwide. The current trends and interests in chemical feedstock from renewable resources secure NR as the material of choice. NR is capable of rapid deformation and recovery along with strain crystallization. To process NR into products with desired features, several ingredients, including vulcanizing agents, activators, accelerators, antioxidants, and fillers, must be incorporated. Among the chemicals used in rubber formulation, calcium carbonate ( $\text{CaCO}_3$ ), kaolin or talc, are commonly used as inert fillers to reduce raw material cost. Although these fillers do not play an important role in improving mechanical or physical properties due to its low specific surface area, they usually attribute to the increasing hardness and stiffness of rubber specimens (Ngamsurat, et al.).

Organization of this work and its layout is described below section wise. Current section consists of introduction of the preparation and characterization of nanocomposites. This includes problem statement and characterization. Survey of the literature is done in the section 2. Literature review includes present theories and survey on natural rubber and nanoparticles. Section 3 includes theories and procedures used in this work for preparation of nanoparticles and



compounding of natural rubber nanocomposites. Section 4 is based on results taken after different testing, conclusion and further Section 5 consists of scope of this work in current industries.

## 2. LITERATURE REVIEW

The term rubber was famed in 1770 by Joseph Priestley (1733-1804), a British chemist who discovered oxygen. Rubber trees grow to a height of about 60 feet tall, in hot damp climates. Latex, extremely sticky and viscous fluid, is collected in a cup mounted on each tree, by slashing the bark to reach the latex vessels, which are like blood veins of the tree. The extracted liquid is 30-40% rubber and may contain relatively high levels of organic and inorganic impurities. The latex is dried, and we have natural rubber NR consists of *cis*-1, 4-polyisoprene molecules biosynthesized by carbon dioxide, making it carbon neutral and not contributing in Global warming. At present 99% of NR produced worldwide is obtained from the domesticated rubber trees cultivation in Southeast Asia, primarily in Malaysia, Indonesia and Thailand. In India, rubber trees are found in the southern coastal belt of Kerala.

Greville Williams (1829-1910) obtained a liquid by distilling rubber in 1860 having an empirical formula ( $C_5H_8$ ) shown by Michael Faraday (1791-1867) for rubber in 1829; he called it "isoprene". Gustave Bouchardat (1842-1918) was the first to obtain synthetic rubber in 1879 but from natural rubber [8], when he observed that heating isoprene with hydrochloric acid produced a rubber like polymer. However, the credit of first truly obtained synthetic rubber goes to William Tilden (1842-1926), when he obtained isoprene by cracking turpentine in 1882. Rubber, technically elastomer, is a unique material which is both elastic and viscous and consists of innumerable micro sized spring-mass dashpot systems. The spring justifies the elasticity which obeys Hooke's Law and increases with increase in stress whereas the dashpot exhibits the viscosity which follows the Newton's Law of viscosity and increases with strain rate. Some of these elastomers strain crystallize and exhibit high tensile strength, flexibility and tear strength with outstanding resistance to fatigue (Najidha, et al.) and the others require reinforcement at microstructural level to obtain adequate static and dynamic characteristics. Polymer and elastomer Nanocomposite reinforced by relatively small amounts of ultrafine Nanoparticles proved exceptionally promising engineered materials with unexpectedly amplified properties (Manias, E. (2007)). The composition of Nano fillers in polymer matrix may vary from 1% to 10% (in mass) or more and are incorporated in addition to traditional additives and vulcanization agents. The structure of nanofillers, based on the shape and size, may be of three type: zero dimensional (nanoparticles/ quantum dots/ nanocrystals), one dimensional (Nano rods/ quantum wire/ Nano fibers/ whiskers) or two dimensional (nanofilms/ thin

films/ quantum well/ nanolayers/ Nano clays/ nanosheets/ nanoplatelets).

Different types of natural rubber (NR)/TCP/OMMT composites were prepared with different amounts of this novel additive. Then, the main properties were researched and compared with the composites directly incorporated with TCP or OMMT. The tensile strength and elongation at break of NR/TCP- 10/OMMT-5 were 15.5 MPa and 673%, respectively, which increased about 10% and 16% compared with that of NR/TCP-10 composite. Meanwhile, the abrasion loss of NR/TCP- 10/OMMT-5 was 0.49 cm³, decreased by 26% in comparison with that of NR/OMMT-5 composite, that is, to 0.62 cm³. Moreover, the limiting oxygen index value was increased to about 34.0% and the thermal stability of which was also improved with the addition of 10 parts per hundred of rubber of TCP and OMMT into NR systems. In addition, the plausible mechanism for the improvement of reinforcing, wear resistant, and flame-retardant properties (Wang, et al.). In the investigation hybrid composites of Epoxy/Nano clay/Glass fiber were prepared by Hand-layup technique. The glass fiber used in this present investigation is E-glass fiber bi-directional: 45° orientation). The composite samples were made in the form of a plate. The wt% of Nano clay added in the preparation of sample was varied, ranging from 1wt% to 5wt%. The fabricated composite materials in the form of plate were cut into corresponding profiles as per standards for impact testing (Sivasaravanan, S. and Raja, V. B. (2014)).

## 3. PREPARATION OF NANOCOMPOSITES

In the recent history, the first observational size measurement of nanoparticles was reported during the first decade of 20th century by Richard Adolf Zsigmondy who made a detailed study of gold sol particles with 10 nm size or less (Zsigmondy, R. (1909)). The synthesis process generally used to fabricate nanoparticles and NcPs are enlisted by Skandan and Singhal (2006) as follows:

- Solid-state synthesis
- Vapor-state synthesis (Inert gas condensation, Plasma-based synthesis, Flame based synthesis, Spray pyrolysis)
- Solution processing (Solution-gelation (sol-gel) process, Solution precipitation, Water-oil microemulsion method)

### 3.1 Solution gelation (sol-gel) process

Sol-gel processing technique comprises solution, gelation, drying and densification. The process involves conversion of the metal alkoxides precursor monomers into a colloidal solution (sol) which forms as an integrated network (gel) of discrete particle or can be deposited as thin film (Wang, et al.). Metal alkoxide precursor is hydrolyzed with water and

the hydrolyzed species are allowed to condensed with each other to form precipitates of metal oxide nanoparticles. The precipitate is subsequently washed and dried, which is then calcined at an elevated temperature to form crystalline metal oxide nanoparticles (Skandan, G., andSinghal, A. (2006)).

### 3.2 Compounding of Natural Rubber Nanocomposite

Formation of cured natural rubber nanocomposite can take place in two processes on their respective equipment as explained in the following lines. The natural rubber with highest purity (dust content < 0.04%), ISNR-3L was obtained as per the specifications of Rubber Research Institute of India (RRII), Kottayam (India). ISNR-3L was a light brown colour extremely flexible rubber sheet with specific gravity 0.93, storage modulus 1.56 MPa and

Mooney viscosity 63 MU. The compounding and reinforcement of nanoparticle in NR is carried out on two roll mill at 14 rpm roller speed and at ambient temperature with compounding ingredients in the same sequence as mentioned in the Table I. As sulfur is the cross-linking agent, it is added after nanoparticles so as to get uniform distribution prior to cross-linking. The compounding time on two roll mill is controlled strictly within 7-10 minutes to avoid the thermal effects due to increase in temperature. Curing and vulcanization is done by hot pressing in Collin molding press at 160°C and with 235 bar pressure. Four hybrid-nanocomposite rubber samples, reinforced with zirconium oxide nanofillers, and one virgin rubber sample without nanofillers, were prepared in the form of square sheet of side 130 mm and thickness 3 mm with nanofillers concentration varying from 0-12 phr (NP-0, NP-5, NP-8, NP-10, NP-12).

**TABLE I: Compounding ingredients of Natural Rubber nanocomposite**

Sr. No.	Ingredients of Nanocomposite NR	Function	Quantity (phr)
1	Natural Rubber(NR)	Matrix	100
2	Zinc Oxide (ZnO)	Curing agent, Anticoagulant	5.0
3	Stearic Acid	Curing agent, Accelerator, Anticoagulant	2.0
4	ZrO ₂ Nanocomposite	Nanofillers	0, 5, 8, 10, 12
5	MBT	Accelerator	1.5
6	Sulfur	Cross-linking and curing agent	1.5

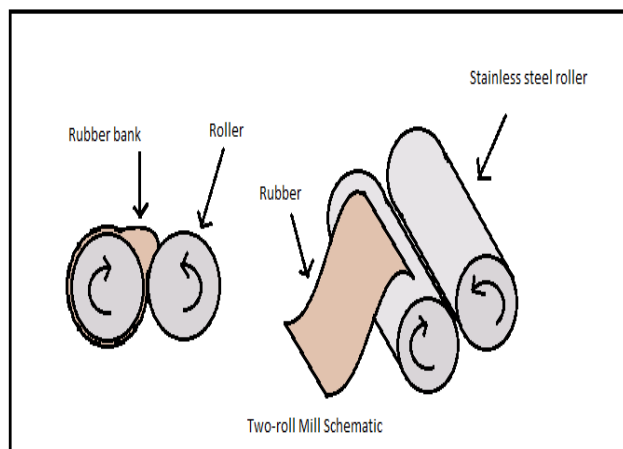
MBT- MercaptoBenzothiazole

#### 3.2.1. Two-Roll Mill

Natural rubber nanocomposite mixing is generally done by melt mixing. Different fillers, accelerators, activators, additives and curing agents are added on two-roll mill in rubber. At the time of mixing the state of natural rubber in masticated or it is slightly softer than the usual. Addition of the above chemical in rubber is done in many passes of the roll. The schematic of two-roll mill is as illustrated in Fig. 1 (b).Mixing was done on a two-roll open mill. An open two roll mill consists of two well-polished metal cylinders placed axially horizontal in symmetry rotating in opposite direction. The gap between the mill rollers can be adjusted, typically between 2 to 20 mm. The speed control of both the roller is separate since both rollers have to operate at different speeds. The speed difference between two rollers is called the friction ratio commonly kept 1.25. The friction ratio generates a shearing action at the tip to disperse the compounding ingredients in the min and to force the compound to stay on one roller. Fig. 1 (a) illustrates uncured rubber after two-roll mill processing.



**Fig. 1 (a) Uncured rubber after two-roll mill processing**



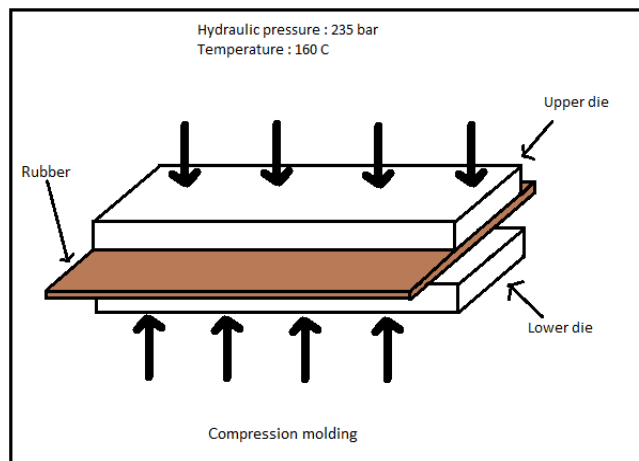
**Fig. 1 (b) Schematic of Two-roll mill compounding of natural rubber**

### 3.2.2 Compression Molding

Collin molding press also known as compression molding is used for curing of polymer and elastomer by increasing their temperature and simultaneously applying pressure on them. The uncured rubber from two-roll mill is kept in compression molding for curing. In molding press rubber is heated to temperature  $160^{\circ}\text{C}$  and pressure of 235 bars is applied. This much pressure causes uniform formation of sheet of cured rubber. The Schematic diagram of compression molding is shown in Fig. 2 (b). It consists of one upper die and one lower die. The rubber is kept between the two dies and it is heated along with 235 bars pressure is applied. The rubber was converted from a tacky viscous material to an elastic solid during vulcanization through incorporation of chemical crosslinks between long molecular chains. The rubber molecular chains are linked to each other by atomic bridges formed by sulfur atoms or carbon-to-carbon bonds. Zinc oxide forms zinc stearate reacting with stearic acid and accelerate the rate at which sulfur vulcanization occurs. Fig. 2 (a) illustrates cured rubber after ejecting from compression molding.



**(a)**



**Fig. 2 (a) Cured rubber from compression molding (b) Schematic of compression molding machine**

## 4. RESULTS

Conclusion of the project can be withdrawn after the completion of characterization of structural, static and dynamic properties of the reinforced Nanocomposite. To conclude the result from the project, we will compare the properties of the material or natural rubber before and after the reinforcement of the Nanoparticle i.e. zirconium oxide. Properties of the material, such as density, percentage elongation, yield strength, natural frequency etc. will be noted down before reinforcement of Nanoparticle and these properties are compared with the properties of the Nanocomposite after the reinforcement. We will see that after the reinforcement of the Nanoparticle in the base matrix the properties of the reinforced material have been dramatically changed. These improved properties will enhance the life cycle of the machine component. Aesthetic and strength of the material also gets improved due to compounding of the Nanoparticle.

### 4.1 Thermal Stability

The DSC and TGA curves of the natural rubber nanocomposites indicate regarding the thermal stability of the polymer compound. The DSC and TGA are interrelated and can be jointly predicted. The weight loss curves indicated that the thermal degradation of nanocomposite NR compound consisted of one main loss step between  $397^{\circ}\text{C}$  and  $420^{\circ}\text{C}$ . All the samples exhibited identical thermal behavior. Thermal behavior of elastomers is measured about its weight loss from TGA and glass transition temperature ( $T_g$ ); the temperature at which polymer changes from a dense solid to a glassy state. The amorphous material exhibit  $T_g$  which is lower than its melting point temperature and characterized through DSC.TGA curves of NR and NcNR are in complete agreement with other researchers results (Mohapatra S. and Nando G. B. (2014)). The weight loss indicated for NR (NP-0) was below  $400^{\circ}\text{C}$  and found linearly increasing with nanofiller concentration.

$T_g$ , have been specifically emphasized by most of the researchers, since variation in  $T_g$  is correlated with changes in diverse transport phenomena as well as chain relaxation behavior which decides regarding viscoelastic performance. It is obvious that the thermal stability increase with increasing the content of hard and rigid NPs with excellent thermal properties. This phenomenon can be attributed to the increment in conductive networks with increase in the conductive Alumina-Zirconia nanoparticles. The inclusion of metallic particles strengthens the molecular network; as a consequence it becomes much difficult to destroy the structure which results in enhanced thermal stability of NcNR (Huang, et al.).

#### 4.2 Mechanical Behavior

The tensile test was conducted on Instron made polymer testing Universal Testing Machine (UTM) on dumbbell shaped cut specimen from the molded NR composite sheet. The cross head speed was 500 mm/min with an extensometer. Ultimate tensile strength UTS and percent elongation were calculated from the characteristics of tensile test. The density and shore-A hardness were determined in separate tests. Three readings in each case were taken and averaged. The reinforcement of nanofillers showed a general increase in mechanical properties with increasing concentration within the elastomeric matrix. To determine the natural frequency theoretically in vibration analysis, the maximum value of modulus was taken in all cases. The nature of stress-strain curves was non-linear for filled NR as justified by literature also. The modulus, UTS and % elongation were found as direct function of nanofiller concentration indicated by an uptrend in these properties. This may be attributed to the excess aggregation of nanoparticles which prevents the elastic behavior of cross-linked chains, reducing the modulus but increasing the strength. The modulus was maximum for NP-12 (2 MPa) whereas the strength and UTS was highest for NP-12 (8.5 N/mm² and 829% respectively).

Almost all researchers are agreed on the enhancement of mechanical properties of filled NR. In the similar trend, these properties were found linearly increasing with non-linear tensile behavior of NcNR. The Nanoparticles may act as resisting and locking object to the entanglements of molecular structure to stabilize them. The molecular packing and dynamics of NcNR can be altered due to reinforcement resulting in non-local stress and strain tensors coupling. The Nano size particles are comparable with the microscopic causes of heterogeneity of the structure which shifts the  $T_g$  altering the relaxation behavior of the elastomeric chains. The mechanical properties are commensurate with the strengthening effect of molecular network, specifically excellent increase in modulus and depend on filler-matrix interface area (Kalfus J. and Jancar J. (2007)).

#### 5. SCOPE

Around the globe concerted efforts are continued in developing lubricants, new materials, and coatings that can lower the friction and wear parameters potentially even under severe operating conditions. Graphite in this area is an excellent member whose lubricating properties are well known. With the development of nanotechnology the nanoform of materials are in superior demand. One of such is the nanoform of Graphite i.e. a self-lubricating material graphene which is famous for its unusualelectrical, mechanical, thermal and very recently because of its tribological properties (Agrawal, et al.). Recently, the interest is growing for alternatives which are the natural fibers based biodegradable plastic composites. The benefits of natural fibers are: biodegradability, renewability, low cost, and low density. This light fiber can give superior specific stiffness and strength that are analogous to the respective synthetic fibers like glass fibers. The promising applications of natural fiber reinforced composites: door, package trays, instrument panels, arm rest, seat back and glove boxes. However, the drawbacks of natural fibers are the high degree of moisture absorption, poor wettability with non-polar polymers, and low-adhesion of untreated fibers with polymer-matrix facilitates the retardation of significant bonding during aging. To seize these difficulties the promising methods are the fabrication of fiber, cautious choice of pair (fiber and matrix), and advance development procedures (Chowdhury, et al.).

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# Wear Prediction of Brake Friction Material $\text{Si}_3\text{N}_4 / \text{SiC}_2\text{Ti}_3$ and Stability Analysis of Brake Squeal by Considering Contact Pressure - Temperature Effects using the Finite Element Method

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**Abstract:** This paper is about wear prediction of brake friction materials in brake disc unit. The newly manufactured unworn silicon based ceramic matrix composite brake friction disc pads are tested under different speeds and different durations of brake application, for prediction of wear on worn-out surfaces. The wear prediction is done on existing as well as on modified brake friction materials to optimize best results. By considering real surface topography of silicon based CMC brake friction materials, a detailed 3- dimensional finite element model of real brake disc assembly is developed for analysis. For wear prediction, the analysis is done for static contact pressure distribution, height distribution and surface topography of the friction materials. The experimental unstable brake squeal frequencies are also analysed for stability, by considering contact pressure and temperature effect.

Vibrations induced due to friction are major problems especially the case in heavy duty applications like aircraft braking system, due to unstable vibrations of disc. To solve this problem both experimental and theoretical approaches are considered. For stability analysis a nonlinear model is developed based on nonlinear contact between the rotors and the stators and mechanism between components of the brake system. Stability is predicted with calculations of the eigenvalues, by using Jacobian matrix for the linear system. Also linear stability theory is considered to determine the effects of different parameters on Stability.

This brake squeal generation during braking is one of the complicated dynamic problem for heavy duty applications. The addition of a constrained layer materials which is made by silicon based CMC to brake pads is utilized as a means of introducing additional damping to the brake system. Additional damping is one way to reduce vibration at resonance, and hence, squeal noise. This work focuses on the use of modal analysis techniques to select different brake dampers for reduce brake squeal by considering contact pressure and temperature effects.

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## 1. INTRODUCTION

A ceramic material is an inorganic and non-metallic compound, often made up of metallic and non-metallic bonding. These ionic compounds form positively charged cations bonding to negatively charged anions. Historically ceramics didn't have many mechanical applications due to the properties of the material. Ceramics are very brittle, have little energy absorb ion and cannot undergo plastic deformation. They have a resistance to high temperature, and can withstand high compressive loads. For example a porcelain ceramic can withstand a compressive load ten times greater than its tensile strength. The purpose of ceramic matrix composites is to allow a greater amount of mechanical applications by reducing the materials brittleness. A CMC material is made up of a monolithic ceramic reinforced with composite fibers to decrease the

crack propagation in the material. This reinforced material can be used in many different applications, since it is no longer limited by its fragile properties. There are many types of CMC materials that contain different mechanical and chemical properties. Some are designed for increased strength, toughness, creep resistance, while others can have greater thermal and electrical properties. The resulting properties are dependent on what fibers are added to the ceramic matrix, and what how the material is manufactured into its shape.

Disc brakes are typically made out of grey cast iron. This material has high tensile strength and can withstand a high temperature before failing. In high performance vehicles the amount of heat generated by friction when braking can be too great so the brakes fail or must be changed often. The failure is due to thermally induced

fractures. Also these brakes can be heavy and susceptible to corrosion, which cause failure.

Other composites have been tested such as Metal Matrix Composite, and Carbon Carbon Composites. The challenges with these materials are the ability to dissipate heat caused by friction isn't optimal at high enough temperatures. A typical grey cast iron disc brake can withstand a surface heat of 400 °C before failure occurs.

## 2. OBJECTIVES OF STUDY

A typical high energy aircraft brake pad unit consists of alternate stator and rotor multi brake discs, called as a heat pack. The brake pads are usually assembled with stator discs. The rotor discs are typically grey cast iron or low alloy (Cr-Ni) steel. The hardness of the rotor is selected to be two times the stator brake pad so that brake pads wear out preferably. At one end of the brake unit, the brake cylinder housing is attached with the pressure plate. The other side of the pressure plate is fitted with brake pads. The other end of the brake unit has a torque tube in which the inner side that is in contact with the rotor disc is fitted with brake pads. The outer side is attached to the hydraulic actuator. Stator brake pads and rotor discs are alternatively placed in between the pressure plate and the torque plate.

The main function of brake pads is to convert the kinetic energy of moving aircraft to the thermal energy by providing the necessary friction during the braking process. The high energy aircraft brake pad is usually designed to stop the aircraft within a short time span of 10 - 30 s depending on the weights (5000-27000 kg) and brake application speeds (180-300 km/h) of the aircraft. It implies that the aircraft stops within a distance of 300-1500 m with a maximum deceleration of 0.3 g. No single pad composition would be able to satisfy the diverse braking requirements. Therefore, high energy aircraft brake pad are tailor-made to the specific aircraft requirements such as kinetic energy, stop time, stop distance, dynamic and static co-efficient of friction, temperature rise, and wear loss. The high energy aircraft brake pad composites are a complex multi-constituents system processed through powder metallurgy for the specific aircraft requirements as described above. The typical brake composites consists of following important constituents:

- (1) Metal or alloy (Fe, Cu, Brass, steel etc.) as a matrix to provide strength, stiffness, specific heat and thermal conductivity properties.
- (2) Particle reinforcements (SiC, Si₃N₄, SiO₂, mullite, Al₂O₃ etc.) to support the brake load, and to provide the necessary friction and wear resistance properties.
- (3) Solid lubricants (graphite, MoS₂, h-BN, PbS, Sb₂S₃ etc.) to stabilize the friction and to provide the brake sequel and seizure resistance properties.

- (4) Fillers (glass, aramid fibers), frictional additives (BaSO₄, CaSO₄ etc.), and ceramic particle wetting agents to provide various properties such as manufacturability, bonding strength, weight reduction, durability, mechanical integrity, brake noise reduction, friction and wear properties adjustment, thermal resilience, hardness, fracture toughness. In the past, development studies on various high energy aircraft brake pad composites such as Cu/SiC/graphite, Cu/silica/graphite/MoS₂, Cu/mullite/ MoS₂, Fe/SiC/graphite and so on were carried out for the Indian defence programs. The numerous combinations of compositions were derived for military aircrafts of 3-19 MJ.

### The silicon based ceramic reinforcement has many advantages:

- (1) High thermal stability and melting point, (2) high fracture toughness, (3) excellent wear resistance, (4) excellent chemical and thermal shock resistance, (5) very low thermal expansion coefficient up to 1900 °C.
- (2) Another advantage of silicon based ceramic matrix composite is that it reacts with the air and forms the silicon oxide (SiO₂) layer which stabilizes the friction coefficient and reduce the wear rate of the composite at elevated temperatures. Also, this layer serves as a protection against the oxidation of composite. These particles were not tried out in the high energy aircraft brake pad yet, at least in India.

In light of the above facts, we have designed a high energy aircraft brake pad composition including silicon based ceramic matrix composite as a ceramic reinforcement for 15 MJ military aircraft.

## 3. PROPOSED WORK

With high thermal properties of ceramics, combined with fiber enhanced strength, ceramics are no longer limited by their fragile mechanical properties. They have high durability, lower density and corrosion resistance that expand the mechanical applications. With new efficient manufacturing techniques CMC's will continue to be used in high performance heat systems while replacing traditional metal components. Silicon-infiltrated carbon-carbon composite is used for high performance "ceramic" brake discs, as it is able to withstand extreme temperatures. The silicon reacts with the graphite in the carbon-carbon composite to become carbon-fiber-reinforced silicon carbide (C/SiC). These discs are used on some road-going sports cars, supercars, as well as other performance cars. Silicon carbide is also used in a sintered form for diesel particulate filters. SiC is also used as an oil additive to reduce friction, emissions, and harmonics.



In military aircraft brakes we can use silicon based ceramic matrix composites brake materials to increase performance. My proposed work will focus on development of new silicon based ceramic matrix composite brake materials for military aircrafts.

#### 4. DEVELOPMENT AND CERTIFICATION OF SILICON BASED CERAMIC MATRIX COMPOSITES MODIFIED WITH C-SiC / Si₃N₄ / SiC₂Ti₃ / C-MoSi₂ / SiC-BN-SiC / C-SiC-B₄C / GRAPHITE BRAKE FRICTION MATERIALS FOR LOW TO HEAVY DUTY AIRCRAFT:

Silicon based ceramic matrix composites are mostly preferred for low to high energy aircrafts brake friction materials. The paper focuses on the prediction / evaluation of the wear, friction and braking performance of the brake friction composite materials for the low to heavy duty aircraft applications. In this paper, the design and advance processing of silicon based ceramic matrix composites modified with C-SiC / Si₃N₄ / SiC₂Ti₃ / C-MoSi₂ / SiC-BN-SiC / C-SiC-B₄C / Graphite brake friction materials have been discussed in details. The qualification tests for the low to high energy aircrafts brake friction materials and the brake units are described with details. The brake testing parameters and different brake design calculations derived from the typical aircraft data and same are presented for both the laboratory and full scale dynamometer tests. A detailed study of silicon based CMCs modified with different brake friction materials are presented to exemplify the steps involved in the design, development and certification for the 2 MJ to 8 MJ energy aircrafts. From the CMCs microstructure, wear - friction surface morphology analysis, the results of brake performance parameters, functional tests and different aircraft trials, it is concluded that the silicon based CMCs brake friction material modified with SiC₂Ti₃ – graphite and C-SiC-B₄C – graphite has a maximum braking life with excellent braking performance.

##### 1. Various composites developed for different aircraft kinetic energies:

Compositions	Aircraft Kinetic Energy
C-SiC / Graphite	6.5 MJ
Si ₃ N ₄ / Graphite	9 MJ
SiC ₂ Ti ₃ / Graphite	15 MJ
C-MoSi ₂ / Graphite	7 MJ
SiC-BN-SiC / Graphite	11 MJ
C-SiC-B ₄ C / Graphite	8 MJ

##### 2. Brake input Parameters for 15 MJ energy military aircraft:

(In a lab scale dynamometer test)

<b>Kinetic energy of two brake pads to be simulated in a lab scale dynamometer test</b>	<b>2570 KJ</b>
Inertia of fly Wheel	61.50 NM ²
Speed of fly wheel	1455 rpm
Brake Force	3748 N

##### 3. Brake input Parameters for 15 MJ energy military aircraft in a full scale test.

Test input parameters	Conditions Simulated for test under	
	Design landing (Normal)	Rejected take Off
Brake Energy	13.95 MJ	15 MJ
Gyrating mass inertia	$8.35 \times 10^{-4}$ Nm-Sec ²	$9.15 \times 10^{-4}$ Nm-Sec ²
Gyrating mass rotation	785 rpm	965 rpm
Brake pressure	14.20 MPa	17.75 MPa
Radial load on the wheel	61.30 KN	KN

##### 4. Following parameters also required to check after test:

- Stopping time or distance, in second.
- Mean dynamic coefficient of friction.
- Brake temperature rise, in °C.
- Rotor wear loss, in mass (gm) and Thickness (mm)
- Brake friction materials (pads) wear loss, in mass (gm) and Thickness (mm)

##### 5. To complete above work following steps are followed:

###### 1. Selection of Material Composition.

###### 2. Typical Prototype Manufacturing.

- Mixing of the Powders
- Powder Compaction
- Pressure Sintering of Brake Pads

###### 3) Certification Qualification Testing:

###### A) Composite Material Qualification Testing:

- Powder characterization (to check purity, particle size distribution, impurities content, apparent density, tap density, compressibility etc.).
- Chemical composition analysis by standards.



- Brinell hardness test (BHN) according to the standards.
- Microstructure characterization according to the standards.
- Complete dimension inspection according to the component drawing.
- Bend test as per standards.
- Laboratory scale dynamometer test according to standards.

#### B) Brake Unit Full Qualification Testing:

- Brake performance evaluation (Normal energy and Rejected take-off energy) by full scale dynamometer test.
- Static torque test.
- Brake stooping test.

#### C) Aircraft trials: Ground test and aircraft landing trials.

**Wear Prediction of Brake Friction Material  $\text{Si}_3\text{N}_4$  /  $\text{SiC}_2\text{Ti}_3$  and Stability Analysis of Break Squeal by Considering Contact Pressure - Temperature Effects using the FEM:**

##### 1. Wear and contact tests:

In this work, a new and unworn pair of brake pads is subjected to different durations of brake application under a brake-line pressure (MPa) and at a rotational speed (rad/s). In the first stage, the brake is applied for 35 Sec. Another 35 sec. is used in the second stage. In the third and final stage, the friction material is run for 1.5 minutes. At the end of each stage, the disc is stopped and then the stationary disc is subjected to a brake-line pressure (MPa) is called a contact test. In order to verify predicted results from the Finite Element analysis, Super Low (SL) pressure indicating film, which can accommodate local contact pressure, is used.

Once the brake is applied the hydraulic pressure is exerted onto the top of piston and the inside of the piston chamber in the calliper housing. This brings both pads into contact with the sliding disc. Since the pads are much softer than the disc, it wears more rapidly than the disc. It is required to measured static contact pressure distributions at the piston and finger pads at the end of all stages of braking. It can be seen from the figures that contact pressure distributions vary as wear progresses in time. The results also show that the area in contact is also gradually increasing. This may suggest that the surface topography of both pads that initially have a rough surface becomes either smoothened or glazed.

In order to visualise the surface topography, measurements are made in the middle of the circumferential direction of the friction material using a linear gauge and a digital scale indicator. Surface topography or height distributions of new friction material at the final stage of braking are also studied. It can be seen that height distribution of the piston pad after braking application is in a similar pattern to the initial distribution, except at the trailing edge. For the finger pad the height distribution is very similar to the initial distribution but in different magnitude particularly at the trailing edge.

##### 2. Finite element model:

A detailed 3-dimensional finite element (FE) model of aircraft disc brake assembly is developed. The FE model consists of a disc, a piston, a calliper, a carrier, piston and finger pads, bolts and guide pins etc. The FE model uses up to 564280 solid elements and approximately 51, 315 degrees of freedom (DOFs). A rigid boundary condition is imposed at disc and of the carrier bracket.

##### 3. Wear simulation:

Rhee's wear formula postulates that the material loss  $\Delta W$  of the friction material at fixed temperature is dependent upon the following parameters:

$$\Delta W = K \cdot F^a \cdot V^b \cdot t^c$$

Where,  $k$  is the wear rate coefficient obtained from experiments,

$F$  is the contact normal force, N.

$V$  is the disc speed, rpm.

$t$  is the sliding time, sec.

$a$ ,  $b$  and  $c$  are the set of parameters that are specific to the friction material and the environmental conditions. This original formula however cannot be used in the present investigation. Since mass loss due to wear is directly related to the displacements that occur on the rubbing surface in the normal direction, Rhee's wear formula is then modified as,

$$\Delta h = K \cdot P^a \cdot (s.r)^b \cdot t^c$$

Where,  $\Delta h$  is the wear displacement, mm.

$P$  is the normal contact pressure, MPa.

$S$  is the rotational disc speed, rad/s.

$r$  is the pad mean radius, m and

$a$ ,  $b$  and  $c$  are all constants which remain to be determined.

Firstly, contact analysis of the FE model is performed similarly to the operating conditions of the experiments

described. From the contact analysis, contact pressure can be obtained and hence wear displacements can be calculated. Having obtained the wear displacements for each wear simulation, nodal coordinates at the friction interface model in the axial direction are adjusted. This process continues until it reaches braking duration, to predict wear on the friction material interface.

#### 4. Stability analysis

There are typically two big different approaches available to predict squeal noise and they are the **transient dynamic analysis and complex eigenvalue analysis**. However, complex eigenvalue analysis is much preferred in the brake research community due to its maturity and other advantages over the transient dynamic analysis. Nevertheless, both analyses should include frictional contact analysis as the first, integral part of the analysis procedure. For complex eigenvalue analysis, contact pressure distribution is essential to establish asymmetric stiffness matrix that leads to the complex eigenvalues. The positive real parts of the complex eigenvalues are thought to indicate possible squeal noise that occurs in a real disc brake assembly. Therefore, it is important to include realistic surface topography of the friction material, especially when wear is under consideration.

In this work, complex eigenvalue analysis will be conducted using ABAQUS software the analysis procedure in order to perform the complex eigenvalue analysis using ABAQUS, five main steps are required as follows:

- Nonlinear static analysis for applying brake-line pressure.
- Nonlinear static analysis to impose rotation of the disc.
- Normal mode analysis to extract natural frequencies.
- Normal mode analysis to extract modes of undamped System.
- Complex eigenvalue analysis that incorporates the effect of contact stiffness and Friction coupling.

#### 5. Brake Squeal

These **two theories** have been investigated and discussed by researchers, but previous brake squeal experience and the majority of research literature considers the geometric instability to be the major mechanism of generation of brake squeal. There are **two types of brake squeal: low frequency and high frequency squeal**. The difference between them is the mode shapes involved in the modal coupling mechanism. For the low frequency squeal, the modal coupling occurs between the out-of-plane modes of the rotor and bending modes of the brake pad. For the high frequency squeal, the modal coupling occurs between the in-plane modes of the rotor. The brake rotor is much stiffer in the in-plane direction than in the out-of-plane direction. Therefore, the resonance frequencies of the in-plane modes of the brake rotor are higher than those of the out-of-plane (bending) modes. Fig. shows the coupling possibilities between brake components.

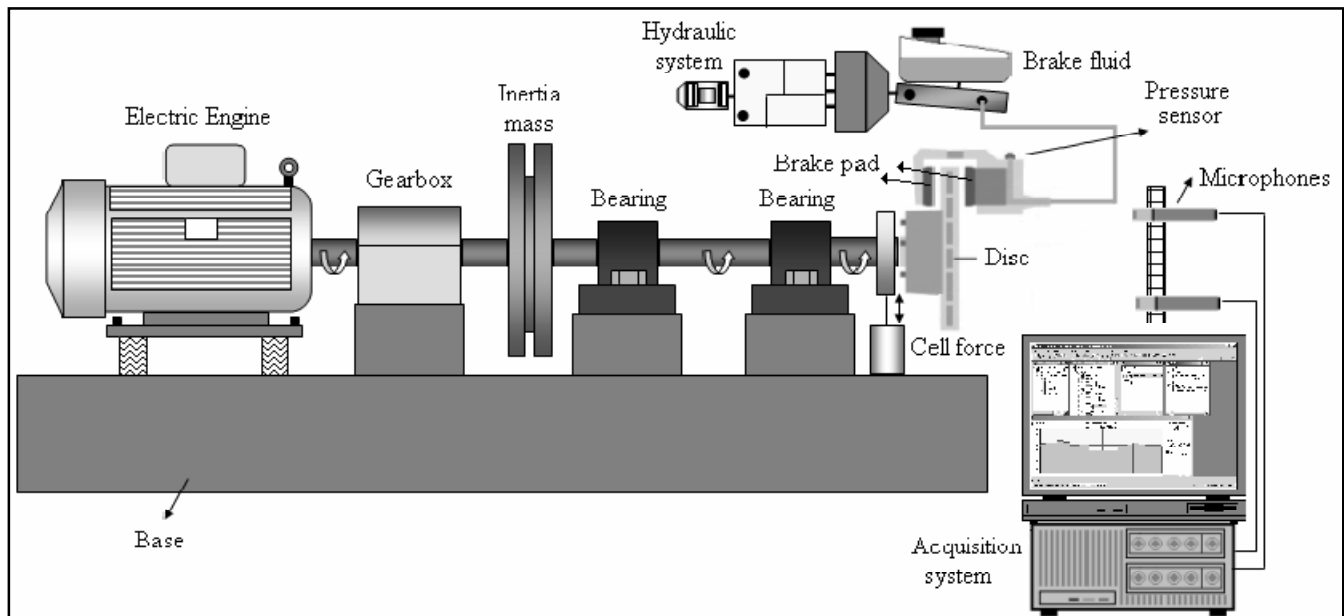


Fig. 1. Proposed schematic diagram of an inertial dynamometer (Different components)

#### 6. Characterization of Brake Noise Generation:

Perhaps one of the most important pieces of information from brake systems is the characterization of the noise generation via dynamometer or vehicle testing. Tests on vehicles are very imprecise, because it is impossible to control the variables like velocity, brake pressure and temperature in order to produce results that represent the characteristics of brake noise generation. On the other hand, dynamometer tests allow us to approach the real behaviour of a brake system in practice, controlling parameters such as rotation, braking pressure and temperature while recording the sound pressure level and frequency of noise occurrences. The disc rotation is achieved by electric motors connected to a shaft with inertial wheels, simulating the inertia effects of the vehicle. Figure shows of the components of an inertial brake dynamometer.

#### **6. Characterization of the Dynamics of Brake Components:**

Squeal noise occurs only when the brake system components demonstrate resonance vibrations. Therefore, it is very important to determine the modal behaviour of the components to understand the problem. Modal analysis of individual components allows us to gain an insight into potential coupling modes, which is, as mentioned before, one of the causes of squeal noise generation. In order to obtain the modal parameters of brake components, each one is modelled through a mathematical mesh to represent its geometry. Pad, rotor and calliper Frequency Response Functions (FRF's) will measure by exciting each component with an impact hammer and measuring the acceleration response with a small accelerometer. Then, the FRF's will process by CADA-X software in order to identify the modal parameters, i.e., resonance frequencies, modal shapes and damping values.

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# Processing and Evaluation of the Mechanical Properties of a Composite Material for Orthopaedic Bone Fracture Fixation Plates

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**Abstract:** The aim of the present study was to develop a laminated carbon fiber/epoxy composite material with unique mechanical and biological characteristics to improve the efficacy of biomaterials. The composite laminates were subjected to various loads and computer controlled UTM to evaluate the properties of the composites with different thicknesses and orientations are investigated by tensile test, bending test and hardness test. The results revealed that the composite material have mechanical properties closer to bone mechanical properties. This phenomenon makes the material attractive for applications that need adequate stiffness like long bone fracture plates. The validation of experimental results was done with results obtained in ANSYS software.

**Keywords:** Fracture fixation, Hand layup manufacturing process, Orthopaedic bone plate, Mechanical Properties.

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## 1. INTRODUCTION

The successful fracture fixation including the use of screws and plates is dependent on many factors such as the severity of the fracture, the health of the patient, and the fixation methods employed. A prevalent way of failure of fixation is due to implant loosening caused by stress shielding. A fractured bone fixated with a metal plate may re-fracture upon removal of the implant. This cause due to the fact that bone does not carry sufficient load during the healing process (Samiezadeh et al., 2015). Metal bone plate cause some problems like metal incompatibility, corrosion, magnetism effect, anode-cathode reactions, including a decrease in bone mass (osteopenia), increase in bone porosity (osteoporosis), and delay in fracture healing (callus formation, ossification) (stress shielding effect / stress protection atrophy) (Bagheri et al., 2013). During the monitoring process of an injured bone using computerized tomography (CT) and magnetic resonance imaging (MRI), these metallic materials appear white in color, which limits the visibility of bone which also appears white in colour. Finally, the fatigue strength of metallic materials is highly dependent on how quickly they can repassivate when oxide layers are removed by fatigue cracks. The inability of metallic implants to repassivate quickly exposes unprotected regions to corrosion, which immediately results in corrosion- fatigue. This can cause a considerable drop

in fatigue endurance limit, which is one of the main reasons for bone plate failure (Bagheri et al., 2014). To address these drawbacks, plating techniques have evolved from the use of metallic plates to the use of composite material plates having low stiffness (Samiezadeh et al., 2015). Although composite biomaterials appear as very attractive solutions for orthopedic implants due to their non-corrosiveness, tailorability, flexibility, and radiolucency. These composites consist of a polymer matrix reinforced by synthetic fibers to achieve acceptable mechanical stiffness and strength. However, their success depends on biocompatibility of both matrix and fibers. With respect the matrix, epoxy is one of the most widely used polymers for orthopaedic and dentistry applications, like coating implantable devices, such as titanium and biosensors. Research has shown that a reduction in plate rigidity and plate-bone contact area decreases the effects of stress shielding. Therefore a balance between stiffness of bone and fracture fixation plate must exist (Samiezadeh et al., 2015).

## 2. LITERATURE REVIEW

The extensive research work has been done in the field of mechanical testing of composite material for the application of bone plates. The literature review of some papers gives more information about their contribution in composite material bone plates.

**TABLE 1: Summary of literature review and experts Opinion**

Main Criteria	Composite Material	Methodology adopted	References
Optimisation of composite bone plates	Composite(E-glass/epoxy)	Finite element techniques are employed to investigate the feasibility of a composite-plated fractured bone construct over a stainless steel equivalent.	Chakladar et al. 2016
Finite Element Analysis of Human Fractured Femur Bone	PMMA Thermoplastic	FE analysis of human fractured femur bone fixation with poly-methyl methacrylate thermoplastic (PMMA)	Dhanopia et al. 2017
Processing and Characterization of Biocomposite for Medical Applications	Poly (butylene adipate-co-terephthalate) / Wollastonite	Biocomposites were characterized for XRD, FTIR, SEM, TGA, cell viability, swelling studies, and tensile properties	Bheemaneti et al. 2016
Optimization of a composite bone plate using the selective stress shielding approach	carbon fibre/epoxy	Classical laminate theory and the finite element method were employed for optimization	Samiezadeh et al. 2015
fatigue analysis of an advanced new carbon fiber/flax/epoxy plate for bone fracture repair	carbon fiber/flax/epoxy	Conventional fatigue testing, thermographic analysis, and scanning electron microscopy (SEM) were used to analyze the damage progress that occurred during fatigue loading	Bagheri et al. 2014
Biomechanical properties of an advanced new composite material for bone plate applications	carbon/flax/epoxy	Mechanical properties were determined using tension, three- point bending, and Rockwell hardness tests	Bagheri et al. 2013

### 3. METHODOLOGY

#### 3.1 Materials

The polymer laminates used in the present experimental investigation are plain weave bi-woven carbon fibre cloth with epoxy resin (LY556 and HY 951) as adhesive with 0/90 fibre orientation and  $\pm 45$  fibre orientation. Each layer of cloth is measuring 0.28-0.3 mm thick. Two different thicknesses of specimens were prepared and the average thicknesses of the laminates were maintained at 4mm and 5mm. The laminated composite specimens are fabricated and tested as per ASTM standards. The laminate was cut to the required size and bonded to the fibre cloth by using an adhesive made from a mixture of LY556 resin & HY 951 hardener in proportions of 10:1 by weight. The surfaces were thoroughly cleaned in order to ensure that they are free from various dusts, oil, dirt, moisture and other chemicals. etc, before curing of the specimens and bonding at room temperature and pressure. The models were allowed to cure for about 24 hours and the thorough bonding of the laminates with the resin is ensured by allowing the laminate to cure for the required period of time.

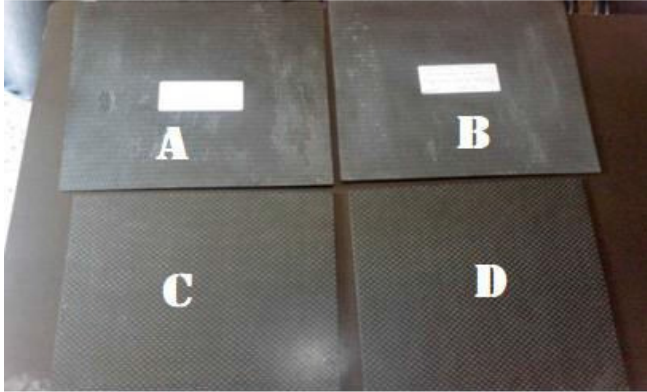
#### 3.2 Preparation of Composites

The hand layup process is a simple method which is adopted for the manufacture of the laminated composites, a mould can be used for this hand layup process the mould can be as simple as a flat sheet or a flat surface

before the layup is done the surface is thoroughly cleaned by applying some chemical agents such as acetone and to this surface a release agent like wax or oil or petroleum jelly is applied to insure the laminated part does not adhere to the mould part. The reinforcing material plain weave bi-woven carbon fibres are cut into required size and are laid on the flat surface of the mould. The fibres of the required size are laid along the required direction as per the design requirements. The resin that is LY556 and hardener HY 951 are mixed in the proportions as recommended by the manufacturer in the required proportions that is in the proportions of 10:1 as suggested by the manufacturer is mixed thoroughly and is applied on the laminated surface to be laminated. The resin is spread evenly on the reinforcing fibres; the resin is squeezed evenly on the surface using a roller and compressed thoroughly with the roller itself. The reinforcing fibres are stacked one above the other and the above mentioned procedure is repeated repeatedly. The laminated composite material is enclosed in a bagging and a recommended vacuum pressure is applied on the laminate to remove the entrapped air bubbles in the layers of the laminated composites. The laminated composites are allowed to cure for 24 hours. These laminated composites are post cured at a temperature of 120°C for 2 hours to ensure the even distribution of the resin and to ensure the proper percolation of the matrix into the reinforcing material. The laminate is ready and this laminate is cut into required size as per ASTM standard and subjected to various tests.

**TABLE 2: Details of Composite Prepared**

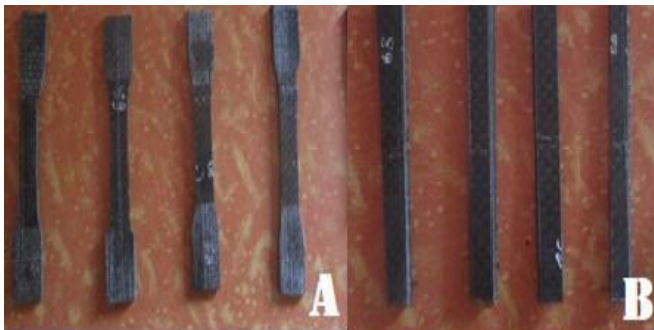
Sample No.	Composite Material	Fibre Orientation in Deg.	Thickness (mm)
A	Carbon/Epoxy	0/90°	4
B			5
C	Carbon/Epoxy	±45°	4
D			5



**Fig. 1. Carbon fibre/Epoxy Composites**

### 3.3 Testing of Composites

For tensile test, bending test and hardness test specimens were prepared as recommended by the ASTM standards (ASTM D-638). After the cure process, the test specimens are cut from the sheet to the proper size as per ASTM standards by using diamond impregnated wheel, cooled by running water. All the specimens are finished by abrading the edges on a fine carborundum paper.



**Fig. 2. Test Specimens a) Tensile b) Bending**

The tension test is conducted as per ASTM D638 standard. The specimen is loaded gradually the loading was done at a controlled rate, the load at yield point is noted down. Further the specimen was loaded till the specimen fails. The test was performed on 5 samples loaded to failure under quasi- static loading conditions. The ultimate strength and ultimate strain were measured just

before the failure. The modulus of elasticity, i.e., slope of the curve, was obtained by applying linear regression to the linear domain of the experimental stress-vs.-strain curve. For bending test specimens are subjected to 3-point bending test and the test is conducted as per the ASTM D790 standards. Using beam theory, the ultimate strength and ultimate strain were measured just before the failure. Also, the flexural modulus of elasticity, which is the ratio of stress to strain at any point on the stress-vs.-strain curve, was calculated. The Barcol hardness test obtains a hardness value by measuring the penetration of a sharp steel point under a spring load. Specimens for the Barcol Hardness Test were prepared and tested according to ASTM D2583. The test specimen is placed under the indenter of the Barcol hardness tester and a uniform pressure is applied until the dial indication reaches a maximum. To obtain a better estimation of Barcol hardness a Barcol Impresser is used. The hardness of composite is a direct result of the resin matrix and how it is cured. The more rigid the resin the higher the level of hardness, whereas the more flexible laminate will have a lower hardness level. As a resin matrix cures and crosslink's, the hardness value continues to rise. When the resin fully cures, the hardness properties will be at the highest value.



**Fig. 3. Mechanical Test Setup a) Tensile Test b) Bending Test c) Barcol Hardness Test**



### 3.4 Failure Mechanism

The steadily increasing utilization of polymer based composites in high performance biomedical applications demands that reliable quality control techniques be developed. In view of the need to characterize a variety as wide as possible of fracture mechanisms testing was carried out in tension and flexure. This is more versatile loading configuration whereby three major failure modes may be induced namely, tensile, compressive and delamination, each comprising a sequence of fracture events. Previous investigations also reported that the ultimate strength of composites might be higher or lower than the polymer matrix material. The ultimate strength of a composite depends on the weakest fracture path throughout the material. Hard particles affect the strength in two ways. One is the weakening effect due to the stress concentration they cause, and another is the reinforcing

effect since they may serve as barriers to crack growth. In some cases, the weakening effect is predominant and thus the composite strength is lower than the matrix; and in other cases, the reinforcing effect is more significant and then the composites will have strengths higher than the matrix. Prediction of the strength of composites is difficult. The difficulty arises because the strength of composites is determined by the fracture behaviours which are associated with the extreme values of such parameters as interface adhesion, stress concentration and defect size/spatial distributions.

Thus, the load-bearing capacity of a laminated composite depends on the strength of the weakest path throughout the microstructure, rather than the statistically averaged values of the microstructure parameters (Bagheri et al., 2013).



**Fig. 4. Macrograph of fracture surface of a) Tensile specimen b) Bending specimen**

### 3.5 Simulation using ANSYS

For present study, simulation is done for two cases i.e tensile testing under different loading conditions and bending test under different loading conditions. For both the case static analysis is carried out. Element type and material properties in both cases are same. The finite element analysis has been successfully made to investigate the tensile strength and flexural strength of carbon fibre epoxy Composite. In this work, properties of epoxy carbon Fibres system have been used and commercially available FE package ANSYS has been used for conducting static analysis. The element chosen was SHELL 181 which is compatible for laminated composite structures. The modelling was performed with four layers at different orientation ( $0^\circ/90^\circ/0^\circ/90^\circ$ ) and  $(+45^\circ/-45^\circ/+45^\circ/-45^\circ)$ . The total thickness of the specimen was maintained at 4 & 5 mm throughout the analysis. With the new approach of reinforcing carbon as Fibres the

influence of these Fibres on the tensile strength and flexural strength were evaluated.

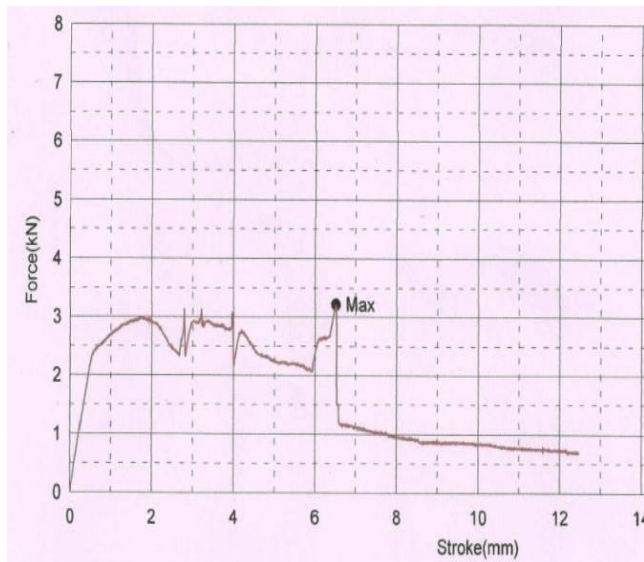
## 4. RESULT AND DISCUSSION

The characterization of the composites reveals that the effect of thickness and orientation on the mechanical properties of composites.

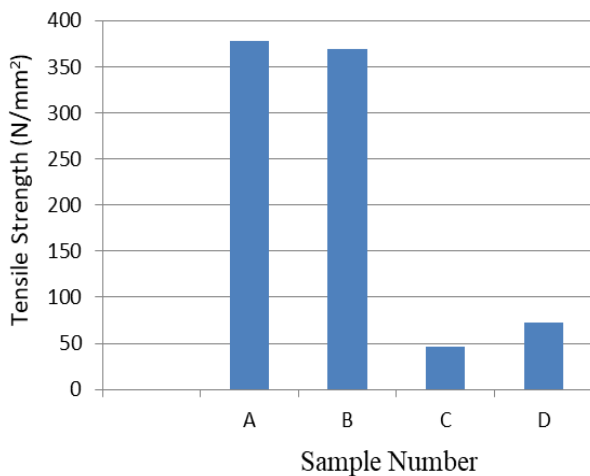
### 4.1 Tension test data

The tensile behaviour of the specimens is shown by plotting Force (N) vs. stroke (mm) (fig.5). All specimens experienced brittle fracture with linear behaviour up until failure. The maximum and minimum tensile strength was observed as 377.49 MPa and 46.94 MPa for A and C type specimen respectively (fig. 6). Failure for all specimens took place at the middle of specimen with catastrophic failure accompanied by an abrupt decrease in stress after reaching a peak value. The micrograph images showed fiber breakage along with

fiber bundle and/or fiber pull-out at the fractured surface (Fig. 4). Most fibers exhibited smooth tensile failure surfaces caused by propagation of the crack in the composite.



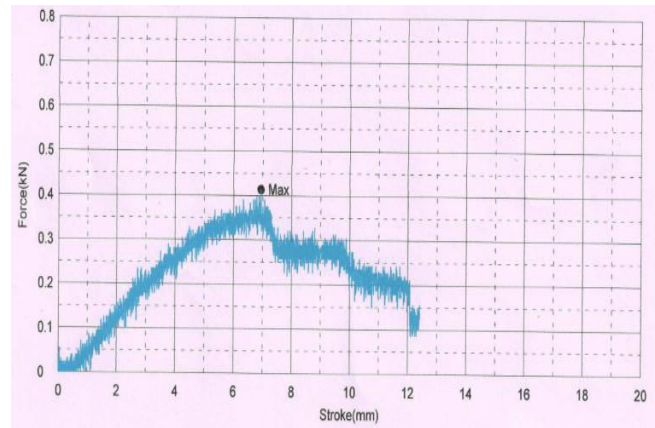
**Fig. 5. Tension test result for CF/epoxy specimen**



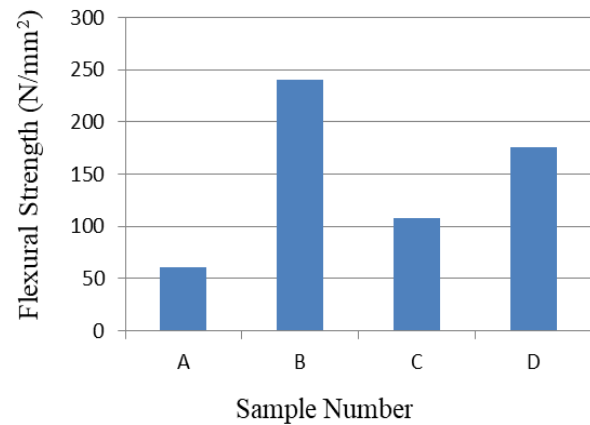
**Fig. 6. Average results of tensile strength**

#### 4.2 Bending Test Data

The behaviour of the specimens in the bending test is shown by plotting force vs. displacement (Fig. 7). All specimens showed linear behaviour in the force-vs.-displacement curve up until failure. The maximum and minimum bending strength was observed as 240.19 MPa and 60.62 MPa for B and A type specimen respectively (fig.8). In all specimens, failure occurred at the outer surfaces due to cracking along the tensile surfaces. The micrograph images exhibited CF failure at the outer surfaces with delamination and/or buckling (Fig. 4).



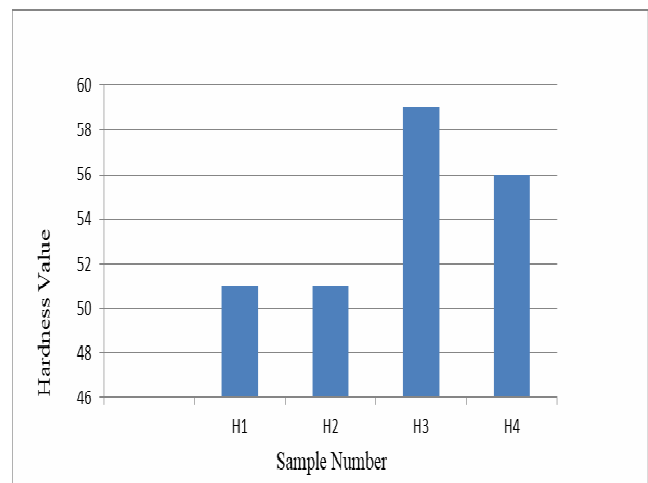
**Fig. 7. Bending test result for CF/epoxy specimen**



**Fig. 8. Average results of bending strength**

#### 4.3. Hardness Test Data

The overall average for Barcol hardness of CF/epoxy composite was 55. Hardness value shows the resin fully cures (fig.9).



**Fig. 9. Hardness values of composite samples**



**TABLE 3: Mechanical properties of the current CF/epoxy Composite, Stainless steel and different bone materials**

Material	Tensile Strength (MPa)	Bending Strength (MPa)	Young's Modulus E (GPa)	Reference
CF/Epoxy Composite	46.94-72.59	107.85-130.45	6-21	-
316L Stainless steel	485	-	193	Ajay Dhanopia, 2017
Bone Cortical Trabecular	106	-	16.7	Saeid et al. 2015
Human cortical bone	50-150	115-155	7-25	G Chen et al. 2009
Femur Cortical bone	43.44±3.62	-	16.7	Ajay Dhanopia, 2017

#### 4.4 Comparison to previous studies

There are scattered results in the literature on the mechanical properties of composites reinforced by natural fibers and polymer fiber. The results of some prior studies on metallic bone plate material, mechanical properties of different bones are summarized in comparison to the present study (Table III). The results of the current study do not perfectly correlate with available results in the literature, due to different fiber orientation, thickness, and various manufacturing methods. Still, the present composite material showed closer mechanical properties compared to the bone material properties in both tension and bending properties.

#### 4.5 Biocompatibility and practical inferences

Metallic bone plates are commonly used for arm bone fractures where conservative treatment (casts) cannot provide adequate support and compression at the fracture site. These plates, made of stainless steel or titanium alloys, tend to shield stress transfer at the fracture site and delay the bone healing rate (N.D.Chakladar et al. 2016). Present study investigates the feasibility of adopting advanced composite materials to overcome stress shielding effects and mechanical properties of the plate to match more closely to the bone. The current ultimate tensile strength and ultimate flexural strength are high enough to carry clinical-type loads, for example, on the human femur (2.5 to 3 times body weight). However, the biomechanical performance of the composite plate implanted on a fracture long bone needs to be further investigated to overcome stress shielding effects by optimising the geometry and mechanical properties of the plate to match more closely to the bone (N.D.Chakladar et al. 2016). The current CF/Epoxy composite material is biocompatible, results from the prior investigation showed that CF/epoxy specimens demonstrated no cytotoxicity and good biocompatibility at all incubations times (i.e., 24, 48, 72, and 96 h) comparable to 316 L stainless steel specimens manufactured from a fracture plate commonly used clinically (G Chen et al. 2009). Similarly, another study

reported the biocompatibility of CF/epoxy based on small animal implantation and tissue cultures with no macrophage thickening or chronic inflammation. CF/epoxy has potential for in-vivo orthopaedic applications (Zahra S. Bagheri et al., 2013).

#### 5. CONCLUSION

This study determined the mechanical properties of a new CF/epoxy composite material developed by hand layup technique. The results revealed that the composite material had closer mechanical properties compared to bone material properties. This phenomenon makes the material attractive for fracture fixation bone plate applications that need adequate stiffness. Moreover, the failure stress in both tension and bending were high enough to carry clinical-type forces. Based on the current results, the CF/epoxy composite has the potential to be used in orthopaedic fracture fixation plate.

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# Comparative Study of Performance Evaluation of Heat Transfer Rate in Automobile Radiator by Using Different Nano Fluids

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**Abstract:** In this paper, the performance of ethylene glycol and water base Nano fluids as an Automobile radiator coolant is determined experimentally. Nano fluid is the combination metallic and non-metallic Nano particles in the base fluid. It can be used to increase the heat transfer rate of various applications such as internal cooling system for automobile system. The heat transfer coefficient of forced convective Nano fluid has been measured and compared with the data of base fluid in an automobile radiator. Nano fluid was prepared by taking water and ethylene glycol in particular ratio with different concentration of Nano powder. In all experiments the Nano fluid made to flow through radiator tubes and airflows constant speed and opposite direction to the tubes with elliptical cross section. The result indicates that increasing the fluid flow can improve the heat transfer performance. The Nano fluid investigated in present work with low concentration increases the heat transfer rate compared to Nano fluid as base fluid. The results are presented in terms of heat transfer coefficient as a function of volume concentration, temperature, and flow rate.

**Keywords:** Nanofluid, Performance, Radiator.

## 1. INTRODUCTION

In automobile industries, new technological research and development has enhanced the demand for high efficiency. There is a requirement of reduction in size and weight in heat transfer systems in transport industries. For increasing the cooling rate of radiator, some efforts are made by using variable types of fins, variable tube arrangement or irregular surfaces. Another way to increase the heat transfer rate is changing the working fluid of radiator.

For heat transfer in radiator using convective heat transfer fluid such as water, ethylene glycol, engine oil individually reduces the performance as oil has a relatively low heat transfer rate. So a high heat transfer system is required to achieve the required heat transfer rate. For increasing the heat transfer rate in radiator fluid, there is one method of adding solid particles in the base fluid in the range of nano size. These fluids are called as nanofluids. Which are in different shapes they can be round or elliptical.

## 2. LITERATURE REVIEW

The thermal conductivity of nano particles is higher than the ordinary fluids which plays a beneficial role in altering the properties of nanofluids also change the fluid features. Scientists have studied the use of nanofluids by using different combinations of nanofluids. As combining the nano particles titanium dioxides ( $\text{TiO}_2$ ), copper oxide ( $\text{CuO}$ ), dialuminum tetra oxides ( $\text{Al}_2\text{O}_3$ ), carbon nanotubes (CNTs), graphene nanoplatelets (GNP) nanofluids with base fluid by different concentration in order to increase the thermal conductivity of convective heat transfer fluid. The study of above nanoparticles mainly focuses on the effect of their volume and mass fraction including specific surface area, shape, and size of the nano particles.

The heat transfer rate can also be enhanced by making a change in the fluid or making different flow as laminar or turbulent. By including nanoparticles in heating or cooling fluids, the heat transfer performance of the fluid can be significantly exceeded.

TABLE I: Summary of literature review

Nanoparticles	Base fluids	Experimental results	References
$\text{Al}_2\text{O}_3$ CNT	Water	Maximum enhancement in heat transfer is found to be	Chavan, Durgeshkumar, and Ashok T. Pise. "performance investigation of an automotive car radiator operated with nano fluid as coolant" Journal of thermal Science and engineering applications 6.2, 2014

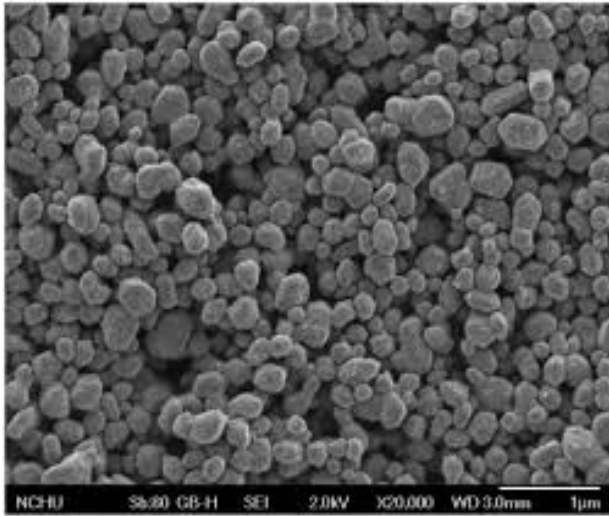
Nanoparticles	Base fluids	Experimental results	References
		90.76% and 52.03% respectively	
CuO	Ethylene glycol	Increases in heat transfer up to 3.8% compared with base fluid	Abc M. Naraki, S. M. Peyghambarzadeha, S. H. hashemabadi b, - parametric study of overall heat transfer coefficient of CuO/water nanofluid in car radiator. International journal of thermal science, 66 2013
TiO2 SiO2	Ethylene Glycol and water	Increament of nussalt no is to be found 22.5% and 11% respectively	Adnan M. Hussein, R. A. Bakar a, K. V. Sharma, heat transfer enhancement using nanofluids in an automotive cooling system, international communication in heat and mass transfer 53, 2014
	(40:60)		
MWCNT	Ethylene Glycol and water	Average heat transfer coefficient is to be increases by 196.03% found at 0.5% volume concentration	ABeriache M'hamed, Nor Azwadi Che Sidik, Mohd Faizal Ali Akbar, Experimental study on thermal performance of MWCNT nanocoolent. International communications in heat and mass transfer 76, 2016
	(50:50)		
ZnO		Enhancement in heat transfer is to be 46% in 0.2% in volume concentration	Hafiz Muhammad ali, Hassun ali, Hassan Liaquat, M.A. Nadir, 'Experimental envistigation of convective heat transfer augmentation for radiaton using ZnO/water nanofluid', May-2015.
	Water		

### 3. PREPARATION OF NANOFLUID

The formation of nanoparticles suspension is the importion step in using nanofluid for heat transfer experiments in this work TiO₂ –water nanofluid, Al₂O₃ water nanofluids and CuO and water mixture is prepared by two step method. The TiO₂, CuO, Al₂O₃, CNTs, nanoparticles of an average size have been provided. As the provided nanoparticles had a hydrophobic surface and they are in clustered form and precipitated when dispersed in water in the absense of a surfacetant as hydrophobic in nature. Addition of the agent may change the fluid properties. The TiO₂ nanoparticles were mixed with 1, 1, 1, 3, 3, 3 hexamethyldisilazane in a mass fraction ratio of 2:1 the ratio the mixture was available then was at 30deg C for 40 KHz After that the Hydrophilic ammonium were suspended on the TiO₂ nanoparticles.



**Fig. 1. General preparation of nanofluid followed by magnetic stirring with sinic process about 2 hr.**



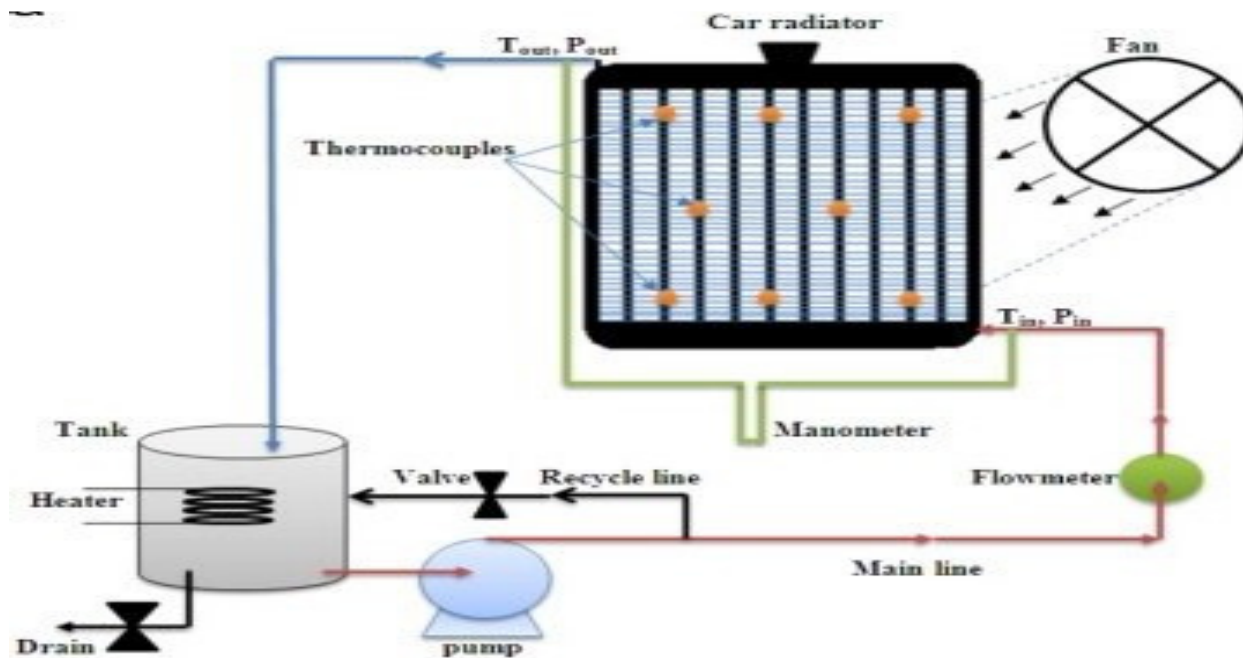
**Fig. 2. Nanoparticles after dispersion**

The soaked nanoparticles were made to dry with rotary evaporator apparatus specific quantity of these generated

nanoparticles were mixed with pure distilled water as the base fluid to make nanofluid in particular volume fraction. The suspension were subjected to ultrasonic vibration at 415W and 24KHz for 2 to 5 Hr to obtain uniform suspension and breakdown the large. Likewise the  $Al_2O_3$  is prepared nanofluid by magnetic stirrer technique it is a rotating magnetic field used to a stir bar immersed in liquid and also heat the solution

### 3.1 EXPERIMENTAL SET UP

The experimental setup includes a reservoir plastic tank, centrifugal pump a flowmeter, tubes valves, electric heater, fan, DC power supply, Digital thermocouple type K for temperature measurement heat exchanger for temperature measurement heat exchanger an electrical heater is inserted inside the plastic storage tank heat the fluid. A voltage regulator provide a power to keep the inlet temperature to the radiator from 50 to 80 C. A flowmeter and two valve are used to measure and control the flow rate. The fluid flow through plastic tubes by a centrifugal pump from tank to the radiator.



The total volume of the circulating fluid is constant in all the experimental steps. The two types of thermocouple type K were fixed for recording the inlet and outlet temperature of the fluid. The digital thermocouple type K is fixed to the radiator surface by insuring more surface area measurement. Two thermocouples type K is fixed in front of fan and other side of the radiator to measure air temperature. A hand held digital thermometer was used to read all the temperatures from the thermocouples. The car

radiator has flat vertical Aluminium tube with elliptical cross sectional area. The distance among the tube row filled with thin perpendicular aluminium fins for the air side axial force fan installed closed to axis of the radiator an electrical heater for heating the working fluid is required having capacity 2000 Watt. Controller is used to maintain the temperature range 40 to 80 C.

There was the heat exchanger in between the hot fluid flowing in the tube side and air cross the tube bundle.

Constant velocity and temperature of the air in the experiment were considered in the order to clearly check the internal heat transfer. The design of the system allowed for filling the heat exchanger from up to down. Table 2 shows the range of the experimental parameter

**TABLE 2: specification of different nanofluids**

Parameters	Al ₂ O ₃	TiO ₂	CuO	GnP
Volumetric flow rate	3 – 5	4 - 5	4 – 8	1-10
Concentration in volume %	0 – 1	0 - 1	0 – 1	0-0.5
Reynold number	2000 - 20000	4000 - 18000	2000 – 8000	110-270
Intet temperature	40, 45, 50	15, 25, 35	35, 45, 54	35, 45

### 3.2. EXPERIMENTAL PROCEDURE

The nanofluid side and the air side convective heat transfer coefficient, Overall heat transfer coefficient, pressure drop, volumetric flow rate, concentration, of fluid in an automobile radiator were studied for various test condition for each test condition the required flow rate and temperature were fixed and experiment was allowed to attained steady state. After attaning the steady state condition the temperature were logged were into a data logger and the pressure drop in nanofluid was noted The nanofluid side and air side and air side convective heat transfer coefficient and the overall heat transfer coefficient were estimate using the measured temarature for the concider test conditions.

### 3.3. USES OF NANOFLUIDS

A) It is used in a lubricant

B) It is used as a additives

1. nanofluid improve the fuel echnomy
2. It also reduce exhaust emisstion

C) It is used in shock absorber

1. It reduce the space and improve the performance of shock absorber by absorbing more vibrations.

2. It was observed that application of nanofluid with low concentration will enhance heat transfer than base fluid.

### 4. DISCUSSION

1. The convective heat transfer coefficient of aluminium nanofluid inhance in correspondence to base fluid by 15-20% in laminar and turbulent flow respectively

2. Using Al₂O₃ nanoparticles is more beneficial than CuO nanoparticles base on the performance index for 1.5 – 2% volume fraction
3. Ethylene Glycol and water mixture and nanofluids enhance thermal conductivity almost upto 35%
4. In experimental study with Al₂O₃ in car radiator 64% enhance was seen at 5 lpm comstant flow rate and renold number 84389 – 41288.
5. CuO at 45 deg centigrade temperature with highest nusselt number and concentration was 0.8% of the convective heat transfer coefficient enhance upto 55%.

### 5. CONCLUSION

The experimental heat transfer coefficient in automobile radiator have review with 5 distinct working liquid pure water, ethylene glycol, Al₂O₃, CuO and water base nanofluid at different concentration and different temperature and the following conclusion were made.

1. Presence of TiO₂ nanoparticles in water can enhance the heat transfer rate of automobile radiator. The amount of heat transfer enhancement depends on the amount of nanoparticles added to the pure water.
2. the thermal conductivity of ethylene glycol and water mixture and nanofluid enhance almost linearly with temperature. At a particular value of temperature corresponding enhancement in the thermal conductivity is less in volume concentration range from 0.2-0.5%.
3. increasing the flow rate of working fluid enhances the heat transfer coefficient for both pure water and nanofluid conciderably while the change in the fluid inlet temparature to the radiator changes the heat transfer performance.
4. The motion of an nanoparticles may be more of the factors in the inhancement of the heat transfer of the radiator fluid.

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# 3D Numerical Simulation of a Synthetic Jet through Three Different Orifice Shapes

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**Abstract:** The focus of this project is to numerically model synthetic jets in quiescent air to study the influence of cavity geometry and boundary conditions of the diaphragm on jet velocity. In this study 3D numerical simulations of synthetic jet with three different orifice shapes is done. Orifice shapes: 1) Circular 2) Square & 3) Oval. The numerical modeling utilized a moving boundary condition with logarithmic oscillating deflection profile applied to the diaphragm. Velocity and pressure profiles are studied at four different positions of diaphragm i.e. a) maximum cavity volume at  $t=0$  b) maximum expulsion ( $t = 0.25T$ ) corresponds to when the diaphragm is at level position and moving with maximum velocity towards the orifice; (c) minimum volume occurs halfway through the cycle ( $t = 0.5T$ ) when the diaphragm is at the highest position (closest to orifice) and the volume of fluid in the cavity is at a minimum; (d) maximum ingestion ( $t = 0.75T$ ) corresponds to when the diaphragm is at level position and moving with maximum velocity away from the orifice. The synthetic jet properties coming out of three different orifice shapes for the same frequency are compared. 3D numerical model of synthetic jet achieves convergence much faster as compared to 2D numerical model. This model is effective tool for studying synthetic jet flow through multiple orifice, which is current hot research topic.

**Keywords:** Synthetic jet, 3D numerical modeling, orifice shapes, logarithmic oscillation profile

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## 1. INTRODUCTION

Synthetic jets are created as a result of volumetric displacement of a fluid filled cavity due to alternative current electric field actuation of a piezo-electrically, electromagnetic or electro statically driven diaphragm. As the actuated diaphragm oscillates back and forth it alternately sucks in and blows out the ambient fluid in and out of orifice on the cavity. Changing parameters such as the amplitude, frequency or the orifice, diaphragm and cavity geometry can change the property of synthetic jet.

A synthetic jet is commonly formed when the fluid is alternately sucked into and ejected from a small cavity by the motion of a diaphragm bounding the cavity, so that there is no net mass addition to the system (B.L. Smith, A. Glezer, 1998). Effect of square, circular and rectangular shape of orifice on impingement cooling of heated surface is studied (M. Chaudhari, B. Puranik et al., 2010). Impingement improved heat transfer using multiple orifice synthetic jet. The maximum heat transfer coefficient is 30% more as compared to that obtained with a conventional single orifice synthetic jet. (M. Chaudhari, B. Puranik et al., 2011). A vibrating diaphragm is simulated as a moving boundary and is compared with other boundary conditions employed in the literature. Moving boundary condition is the most realistic boundary condition for the simulation of synthetic jet. Synthetic jets are more affected by changes in the geometric parameters of the orifice than those of the cavity (Manu Jain, Bhalchandra Puranik et al.,

2011). The simulation method with dynamic mesh is more reasonable because it is realistic motion of piston in fact, and the time cost is not more heavily than velocity inlet boundary condition (Xiaoyong Ma, Hongtao Guo et al., 2012). Displacement of oscillating diaphragm is modelled by using parabolic & logarithmic displacement equations. For flat diaphragm, logarithmic displacement profile gives more accurate result for numerical modelling (Poorna Mane, Karla Mossi et al 2007). Study of the flow patterns of circular synthetic jets issuing into a quiescent flow at low Reynolds numbers are studied numerically confirm the presence of the three jet flow regimes, i.e. no jet formation, jet flow without rollup and jet flow with rollup reported in the literature (Qingfeng Xia, Shenghui Lei et al., 2014). Numerical investigation of a new promising technique for a 3D synthetic jet; this methodological analysis is based on the computational Fluid Dynamics (CFD) Computers codes in the aim to justify the validity of the model used and its ability (Samir Laoued, Abbes Azzi et al., 2012). Cavity shapes affect the centreline jet velocity of synthetic jet (Mark A. Feero, Philippe Lavoie et al., 2015).

The rest of this paper is organized as follows. Section 2 briefly reviews the literature on Numerical modeling of synthetic jet. Section 3 presents the Problem description. Furthermore, methodology for numerical modeling is described in section 4. Finally, Result and discussion are presented in section 5 followed by conclusion in Section 6.



## 2. LITERATURE REVIEW OF THE SYNTHETIC JET

**TABLE 1: Summary of literature review and experts Opinion**

Main criteria		References
Cavity shape	Effect of cavity shape on properties of synthetic jet	Mark A. Feero et al., 2015, Manu Jain et al. 2011, UdaysinhBhaskar et al 2015
Numerical modeling Boundary condition	Velocity boundary condition	Qingfeng Xia et al., Manu Jain et al. 2011
	Moving piston boundary condition	Manu Jain et al. 2011
	Moving Boundary condition of diaphragm	Xiaoyong Ma et al., 2012, Manu Jain et al. 2011, Samir Laoued et al 2012, Poorna Mane et al 2007
Heat transfer	Orifice shape	Mangate et al, 2015
	Distance between orifice and plate z, frequency	Chaudhari et al, 2010, P. Valiorgue et al 2009

## 3. PROBLEM DESCRIPTION

The focus of this project is to numerical model synthetic jets in air to study the influence of orifice geometry on jet flow. After developing the numerical model that is validated against experimental data, the model can be used to predict results for various conditions that are not experimentally feasible to measure.

### *Objectives of the current research are:*

1. To develop a 3-D numerical model of synthetic jet actuators, SJA, in air using numerical fluid modelling software Star CCM+.

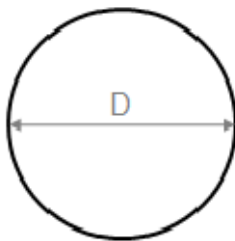
2. Compare and validate numerical results of velocity profiles to the experimental data of various tested designs
3. To study the effect of orifice geometry on the jet flow by comparing three orifice geometries i) Circular ii) Square & iii) Oval shape. Configuration

A schematic of the synthetic jet actuator design configuration tested is shown in Figure 1.

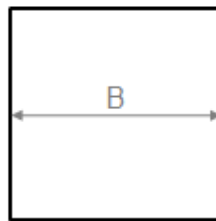
For comparison following orifice shapes are selected  
1) Circular 2) Square & 3) Oval

For comparison hydraulic diameter is kept same for all the three orifice geometries.

**Circle: Dh = D**



**Square: Dh = B**



**Oval:**



$$D_h = \frac{4BC(64-16E^2)}{(B+C)(64-3E^4)}$$

$$E = \frac{B-C}{B+C}$$

**TABLE 2: Dimensions of synthetic jet actuator**

Parameter	Hc	D _D	H _O	D _O	δc
Value	9.55mm	60mm	1.6mm	3.67mm	0.396mm

Hc: Height of cavity      D_D: Diaphragm diameter      H_O: Height of orifice

D_H: Orifice Hydraulic diameter      δc: Amplitude of vibration of diaphragm

#### 4. METHODOLOGY

3D model is prepared for the numerical simulation. Boundary conditions are specified for each of the edges that comprise the cavity and the ambient fluid into which the jet is expelled. As shown in Figure, the diaphragm and cavity are walls; the ambient is specified with pressure inlet and pressure outlet. Logarithmic profile the instantaneous displacement is shown below by equation I.

$$\delta(r, t) = \frac{\delta_c}{2} \left[ 1 - \frac{4r^2}{D_D^2} + \frac{8r^2}{D_D^2} \ln \left( \frac{2r}{D_D} \right) \right] \sin(2\pi ft) \quad (1)$$

Where  $\delta_c$  is the diaphragm center peak-to-peak displacement,  $r$  is the radial distance from the center of the diaphragm,  $D$  is the diaphragm diameter and  $f$  is the actuation frequency.

Differentiating equation 1 to obtain the instantaneous logarithmic diaphragm velocity,

$$u(r, t) = \pi \delta_c f \left[ 1 - \frac{4r^2}{D_D^2} + \frac{8r^2}{D_D^2} \ln \left( \frac{2r}{D_D} \right) \right] \cos(2\pi ft) \quad (2)$$

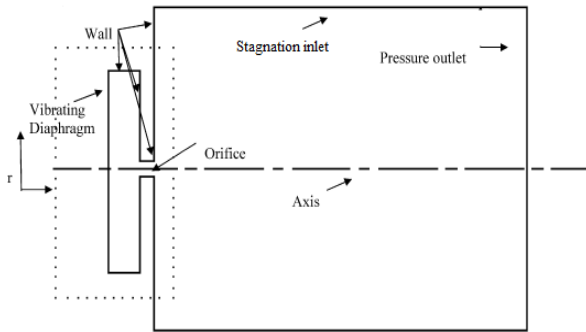


Fig. 1. Synthetic Jet Geometry Boundary Conditions.

Numerical model is validated with the results of Mane et al2007.

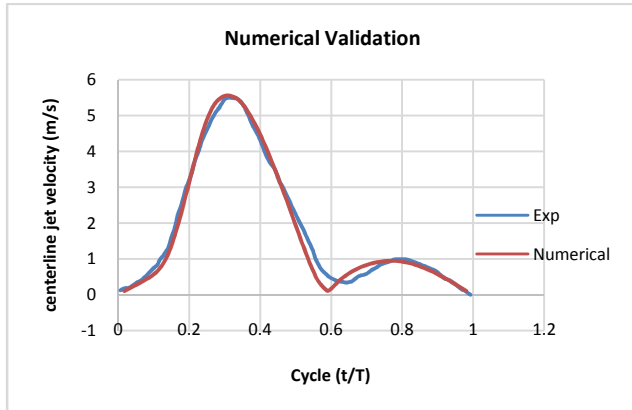


Fig. 2. Validation of centerline velocity(m/s) vs Cycle (t/T)

#### 5. RESULT & DISCUSSION

Figure 3 shows the centreline jet velocity of synthetic jet coming out from a circular orifice at different frequencies. It is observed that the velocity increases as the frequency of diaphragm actuator increases. However the velocity profile is same for all the three cases (i.e. 50Hz, 80Hz & 100Hz). From the graph we can see that the maximum velocity is obtained at 0.3T of a cycle i.e. at  $t = 0.3T$  which is slightly after maximum expulsion condition at  $t = 0.25T$ . Figure 4 shows circular orifice generates higher velocity jet at the same frequency for same hydraulic diameter and same cavity conditions. For same frequency of 100 Hz circular orifice give highest peak velocity of 11.3 m/s followed by oval orifice which give a peak velocity of 10.68 m/s and the last square orifice which gives peak velocity of 9.09 m/s.

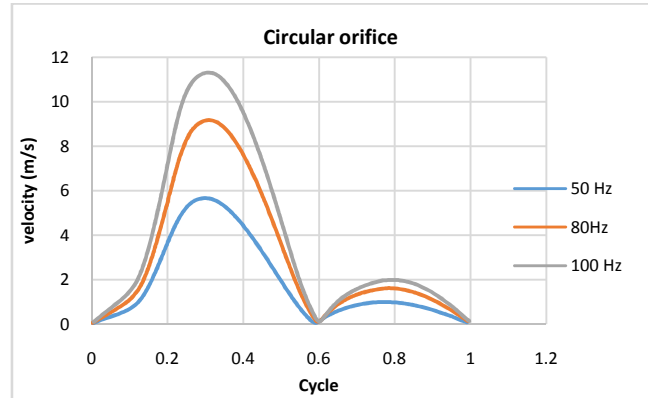


Fig. 3. Variation of centerline velocity of jet over a cycle for different frequencies

Figure 4 also shows that the peak velocity is achieved earlier in circular orifice jet than the oval and square orifice jet respectively. For circular orifice peak velocity is achieved at 0.3T of the cycle whereas for oval orifice jet attains peak velocity at 0.31T of cycle and square orifice jet attains peak velocity at 0.33T of the cycle.

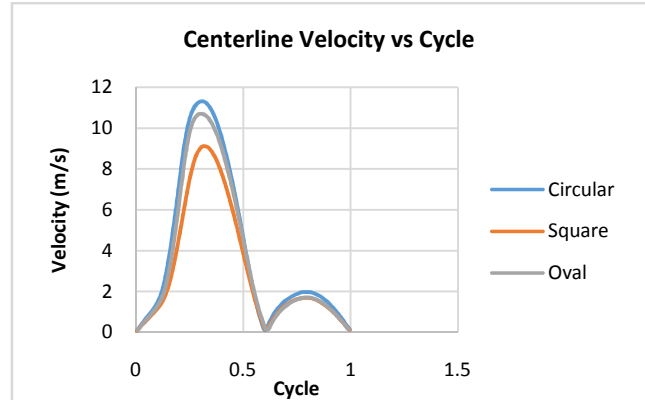
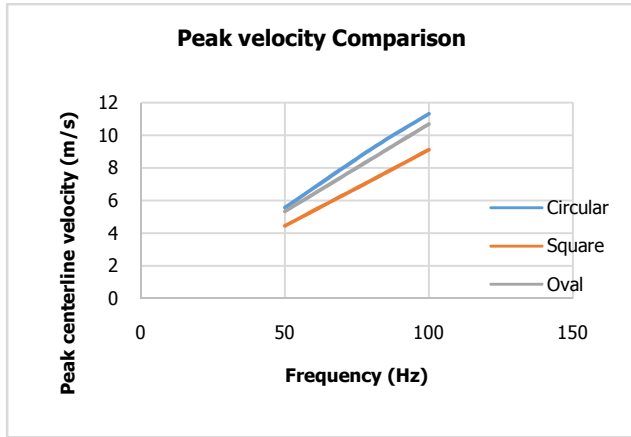


Fig. 4. Comparison of centerline velocity of jets through different orifice shapes for f=100Hz

From the Figure 5 we can see that jet velocity increases with increase in frequency linearly for all the three orifice conditions. However the slope of the curves tell that circular orifice gives higher velocity jet i.e. maximum centerline velocity increases more rapidly with the increase in frequency as compared to the square orifice jet and oval orifice jets. More maximum centerline velocity leads to enhanced heat transfer rate.



**Fig. 5. Variation of peak centerline velocity of synthetic jet with frequency of vibration**

This can be justified by for identical cavity dimensions and for same hydraulic diameter condition of all three cases, circular orifice has minimum area followed by oval shape and square shape orifice. Thus maximum velocity is highly dependent on the area of the orifice. For identical diaphragm size, diaphragm displacement and cavity dimensions over a cycle volume swept by diaphragm is same. Thus during the expulsion cycle air inside the cavity is pushed out and by the continuity equation  $A_1V_1 = A_2V_2$  For lower area of orifice velocity of jet is higher.

## 6. CONCLUSION

In this study 3D numerical simulations of synthetic jet with three different orifice shapes is done. Orifice shapes: 1) Circular 2) Square & 3) Oval. The numerical modeling utilized a moving boundary condition with logarithmic oscillating deflection profile applied to the diaphragm. The code was validated with the experimental and numerical results of Mane et al. The validated numerical model is used to study the synthetic jet characteristics coming out from different orifice shapes. For the study Square and oval shaped orifice are selected to compare the results with circular orifice. Hydraulic diameter is kept same for all the three orifice shapes (i.e. Circular, square & oval).

At the maximum cavity volume step which is at the end of ingestion cycle the air is coming inside the cavity with high velocity which cause vortex generation inside the cavity. The incoming jet hits the diaphragm causing high pressure at the centre of the diaphragm. Maximum expulsion and

maximum ingestion steps show similarities with each other but in reverse nature. Maximum velocities in both the cases are same but in reverse direction. Comparing the pressure plots in these cycle shows that during maximum expulsion cycle a low pressure is observed at the entry of the orifice corners while during for maximum ingestion step lower pressure is observed at the orifice exit corners. As the frequency goes on increasing the velocity of jet also increases. For the frequency range of 50Hz to 100Hz the peak velocity for all three jets increases linearly, however increase in peak jet velocity is more rapid in case of circular orifice followed by oval orifice jet and lastly square orifice jet.

Circular orifice jet attains peak velocity at 0.3T of a cycle. Oval orifice jet attains peak velocity at 0.31T of a cycle. Square orifice jet attains peak velocity at 0.33T of a cycle.

The numerical model can be used to study the effect of different parameters on synthetic jet such as diaphragm displacement, cavity volume, orifice shapes etc. As the numerical model is 3D a multi orifice numerical jets can also be simulated and the jet properties can be studied.

Study of synthetic jet coming from multiple orifice can also be studied from 3D numerical model.

The maximum velocity obtained in synthetic jet is directly related to heat transfer rate obtained by the jet at the given frequency. Thus by comparing the peak velocity of synthetic jet from different shapes of orifice we can compare the heat transfer rate of these jets.

Recent studies shows that multiple orifice synthetic jet gives more heat transfer rate as compared to single orifice synthetic jet, such different configurations of orifice can be easily simulated using 3D numerical model.

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# Computer Aided Modeling of Three Purpose Metal Bender Machine and its Experimental Weight to Cost Analysis

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**Abstract:** The main problem that people, who are occupied with doing various metallic projects and generally constructions, is the bending of metallic pieces. The reason that this problem is arisen during these projects is because the metallic pieces need a lot of pressure, strength as well as accuracy to be bent. There are many machines to be used to achieve this, but the cost is high. Although, the metal bender machine has been already made by industrial team of experts, the particular model was not affordable by anyone as more specialized machines were needed to be made than the ones that can be found in any college workshop. Therefore, an attempt has been made through this paper to propose an affordable and user friendly CAD Model of Metal Bender Machine which initiate three pyramidal roller mechanism for three different purposes of bending.

**Keywords:** Problem, CAD Model, Pyramidal roller mechanism, Three purpose

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## 1. INTRODUCTION

The Computer Aided Modeling of Three Purpose Metal Bender Machine is formulated by designing a horizontal, reticulated frame of square tubes of 60mm x 60mm x 2mm thickness, which has been placed as the bottom structure. The bottom structures of the machine as well as the horizontal frame are both motionless. A second frame with the same requirements of the structure includes the horizontal frame and it moves upwards and downwards within two metallic channels that we have designed. The motion of the moveable part is vertical in the motionless frame. Any moves occurred in the frame are supported with the use of a hydraulic jack that exerts pressure up to 6 tonnes.

This jack moves with the help of a lever that has been attached on it. Thus, moving the lever, the moveable metallic frame moves vertically on the horizontal framework with the potential to exert pressure of 6 tonnes. Then, we design and placed two metallic axes of 38mm thickness at the frame which remains still and another one the same at the moveable frame. In this way, placing the metallic object between the two axes and moving the lever of the jack, we make the object incline and bend.

At the two edges of the three axes, we placed screws and proposed special channels for wedges in order to be able to put attachments according to the shape and the thickness of the metallic objects that we need to bend. Taking benefit from our structural model, we made a wheel that is placed at the central axis which is located at the moveable frame. As a result, giving the inclination that we prefer and

orbiting the wheel continuously, which will manage a constant inclination at the metallic objects that we want to bend such as tubes, square tubes, knife blades and others. Both sides of the axes will be modified as the one side can be used for a new machine in the future.

Also, we designed to provide special attachments for the edges of the axes made of metallic, perforated axes and plastic for bending the tubes and aluminum. Therefore, it will achieve to bend iron at the center of the metal bender as well as at its edge. At the central point of the metal bender machine, objects of a larger diameter are placed as it is supported by both sides with housing bearing while at its edge smaller in size objects are put for bending but in various shapes and kinds. Also, at the edges, we can achieve a larger inclination and make circles and arrows smaller in diameter.

Furthermore, we have design our structure to function vertically and horizontally according to the available space that we have and it will be implemented having the perspective to transform our structure into an automatic machine in the future using a motor if necessary. It will be highly recommended in future after completion of project, as it is very simple and useable as well as useful to thousand other structures and essential for us and to many other small fabrication workshops.

## 2. LITERATURE REVIEW OF THREE PURPOSE METAL BENDER MACHINE

A lot of literature review was carried out to identify any scope of further design and optimization in the terms of

weight analysis so as to make the design sleek and portable. The major necessity for any bending operations is the kind of mechanism used in any particular machine. Literature Review also reveals that very few and limited studies are available on pyramidal three roller bending mechanism. Also, more prominently the plastic tube/pipe bending by the use of plastic conduit is rarely identified for plastic pipe bending operation.

K.Baines (1997) explains that the traditional techniques for large size semi-cylindrical workpiece are stamping or incremental air-bending. Yet stamping method requires a powerful and large work-table press and large expensive forming dies, the cost to produce various parts on a small scale is too high. Although the incremental air-bending forming can manufacture high accuracy workpiece, it would consume high mold cost, much time as well as labor cost. It should be noted that the roll-bending process is an efficient technique for forming a metal plate into a cylindrical or conical shape due to its simple configuration, such as the manufactures of wind towers in energy engineering and tubular sections in civil engineering, and curved plates in ship hulls and large steel structures. In recent years, much work has also been investigated on modeling and simulation for roll bending of sheet metal; there are lots of literatures on manufacturing and finite element simulation of roll bending forming. However, it only applies to the roll bending of small workpiece; little is reported on that of the large workpiece. Therefore, an analytical approach should be obtain to optimized tool and process parameters of workpiece-forming, and check its applicability from the viewpoint of making the production process more efficient.

M.Hua (2002) reveals that to ensure efficiency in the production of large workpiece in industrial practices, analytical modeling and numerical simulation for roll bending forming of sheet metal are taken as the subject to be investigated. The position of the inner roll which determines the final radius of the bent workpiece will be predicted by both analytical and finite element approaches. Finally, the results of these two approaches are compared and validated with experiments.

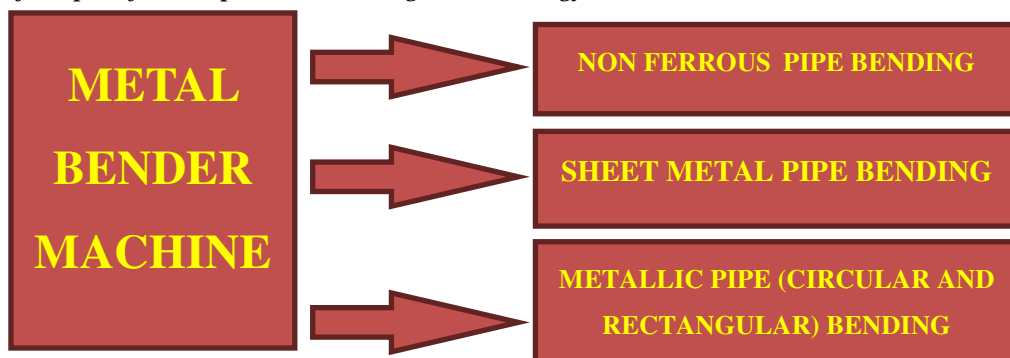
Literature Review also signifies that the roll bending process is an efficient technique for forming a metal plate into a cylindrical shape. This is a continuously local plastic forming process. In this, plate is passed through the set of rolls to get the desired formed shape. Over the last two decades, extensive research and development have been dedicated to roll bending process. Unfortunately, even though some publications on analyses of three roll bending process in cylinder roll bending can be found, investigation of roll bending process with three dimensional models are not yet available for the manufacturing industry. The methods published are mostly analytical and used for the purpose of understanding the process. The roll bending is tedious iterative method which requires lot of skill which dramatically affects the productivity which presents a dynamic simulation work on the plate roll bending process for the production of a cylindrical shell. This includes three roll pyramidal configuration of roll bending machines with cylindrical rolls. This will help in reduction of various defects while manufacturing the cylindrical shell.

### 3. METHODOLOGY

The methodology based on Computer Aided Designing to draft a Optimized Model of Metal Bender Machine explicitly focuses on the five important terms:-

- 1) Divergence – Exploring possibilities and constraints of inherited situations by applying critical thinking through qualitative and quantitative research methods to create new understanding toward better design solutions.
- 2) Transformation – Redefining specifications of design solutions which can lead to better guidelines for traditional and contemporaory design activities or multidisciplinary response.
- 3) Convergence – Prototyping possible scenarios for better design solutions that incrementally or significantly improve the original inherent situation.
- 4) Sustainability – Managing the process of exploring, redefining and prototyping of design solutions continually over time.
- 5) Articulation – the visual relationship between parts and the assembly.

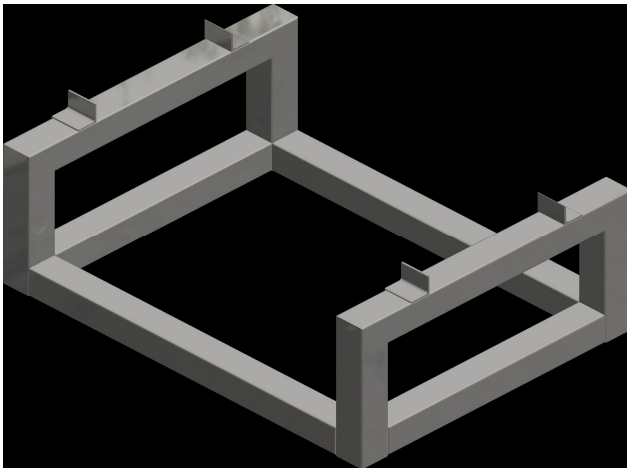
#### 3.1 Statement of Purpose for Computer Aided Design Methodology



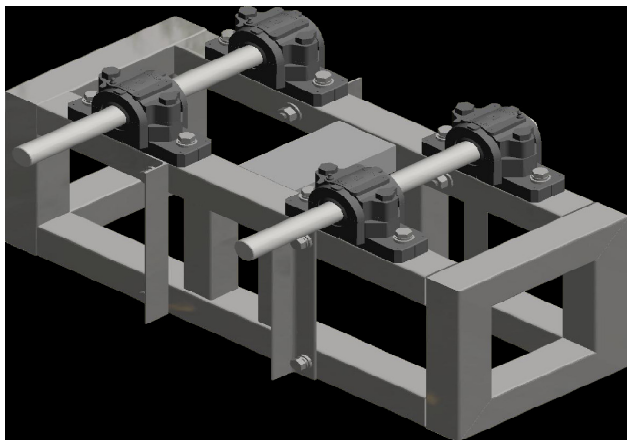
### 3.2 Steps involved for Computer Aided Design Methodology

This Methodology involves simultaneous designing and correlating the same with weight to cost analysis in order to calculate the minimum total weight of the model structure and to give first priority in our research work to induce a portability aspect in the structure. The above weight analysis has proved us to be instrumental for calculating the overall cost of structural model from actual experimental point of view. The design calculations are performed in the dimensions of millimeters with due respect to the specific gravity of material for the Design Model i.e.  $7.835 \times 10^{-6} \text{ kg/mm}^3$  for MILD STEEL Material.

**Step 1:** Design and 3D Modeling of Bottom Structure of the Three Purpose Metal Bender Machine in SolidWorks Software along with angle plates and calculating its weight from the formula,  $\text{Mass} = \text{Area} \times \text{Length} \times \text{Specific Gravity of material}$ . This Bottom Structure acts the buffer frame of the proposed structural model.



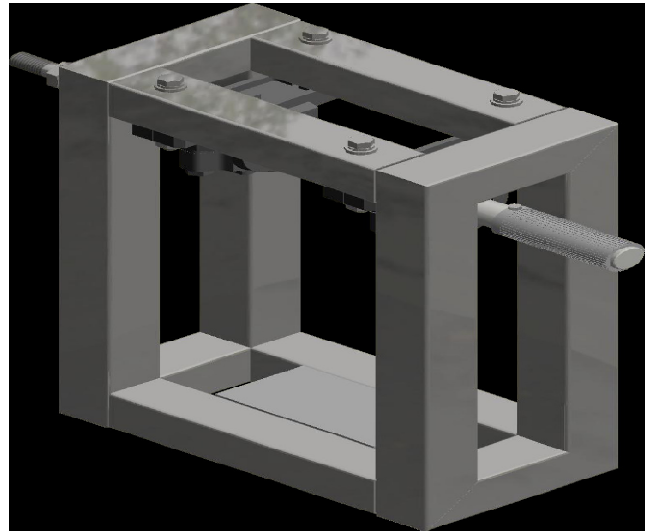
**Fig. 1. Bottom Structure**



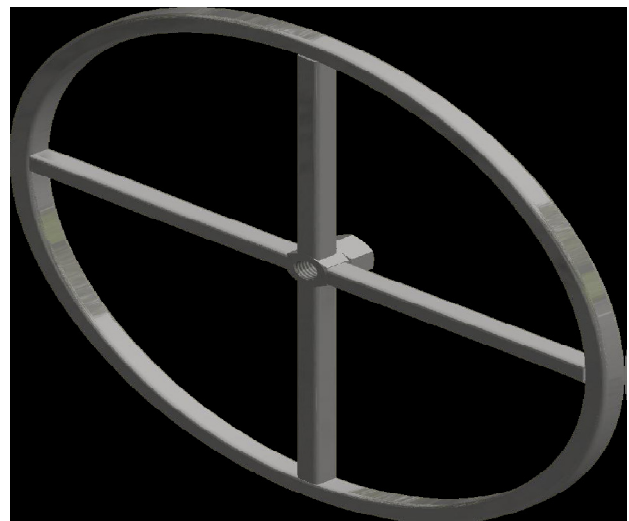
**Fig. 2. Middle Structure**

**Step 2:** Design and 3D Modeling of Middle Structure of the Three Purpose Metal Bender Machine in SolidWorks Software along with housing bearing and bright bars and calculating its weight from the formula,  $\text{Mass} = \text{Area} \times \text{Length} \times \text{Specific Gravity of material}$ . This Middle Structure acts the motionless frame of the proposed structural model.

**Step 3:** Design and 3D Modeling of Top Structure of the Three Purpose Metal Bender Machine in SolidWorks Software along with friction shaft and calculating its weight from the formula  $\text{Mass} = \text{Area} \times \text{Length} \times \text{Specific Gravity of material}$ . This Top Structure acts the moving frame of the proposed structural model. It will also include the designing of wheel structure to drive the three roller mechanism.



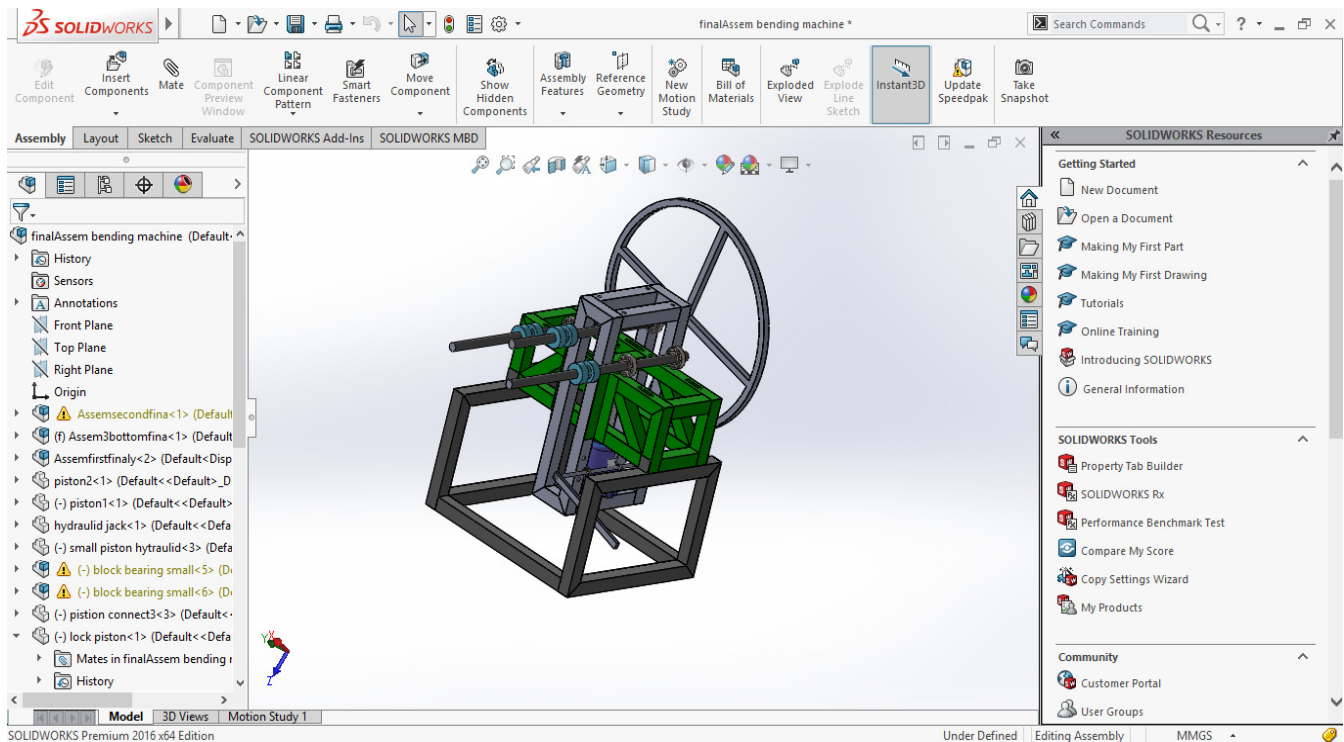
**Fig. 3. Top Structure**



**Fig. 4. Wheel Structure**



**Step 4:** Converting the above four parametric models into direct/explicit model i.e. assembly.



**Fig. 5. Solidworks Direct/Explicit Assembly Model**

#### 4. EXPERIMENTAL ANALYSIS OF STRUCTURAL MODEL THROUGH WEIGHT TO COST ANALYSIS AND ITS RESULTS.

**TABLE 1: Weight to Cost Analysis**

Sr.No.	Component	Mass (kg)	Quantity	Unit cost	Total Cost
01	Bottom Structure	19	1	45/kg	855/-
02	Angle Plate (For Bottom Structure)	0.3	4	45/kg	14/-
03	Middle Structure	21	1	45/kg	945/-
04	Bright MS Bars/Shafts (STATIC)	8	2	55/kg	440/-
05	Angle Plate (For Middle Structure)	1.5	4	45/kg	68/-
06	Top Structure/Moving Structure	19	1	45/kg	855/-
07	Bright MS Bars/Shafts (MOVING)	5	1	55/kg	275/-
08	Friction Shaft (Spline Headed)	0.7	1	45/kg	32/-
09	Wheel Structure	5	1	45/kg	225/-
10	Middle Bars (Hydraulic Jack and Top + Middle structure)	3	4	45/kg	135/-
	<b>TOTAL</b>	<b>82.5</b>	<b>-</b>	<b>-</b>	<b>3844/-</b>
<b>Other components (Not included in Design Calculations)</b>					
11	Housing Bearings	1.8	6	150/piece	900/-
12	Hydraulic Jack	4.6	1	1200/-	1200/-
13	Hexagonal nuts and bolts	0.2	20	-	500/-
	<b>TOTAL</b>	<b>89.8</b>	<b>-</b>	<b>-</b>	<b>6444/-</b>



From the above Table I, the results clearly indicates that the total weight of the proposed Model of Metal Bender Machine is comparatively less than other Industrial Metal Bender Machines having a weight of 89.8 kg with a cost of just 6444/-. Assuming the manufacturing cost to be 10% of the purchased raw materials the Total cost of the Proposed CAD Model in actual practice will lead to approximately 8500/- only, when intended for manufacturing.

Such a Optimized model in the terms of reduced weight and reduced cost leads to increase in productivity for small scale productions and bending operations.

## 5. CONCLUSIONS

This developed analytical model with the use of computer aided design on the basis of three roller pyramidal mechanisms enlist the below the important conclusions:-

- 1) The weight to cost results show that this method of optimization of three purpose three roller metal bender machine are reasonable and effective.
- 2) For the small to medium scale fabricators, where the volume of production does not affect the acquisition of three roller mechanisms, such proposed model can be proved to easy in the terms of machine handling and less labour skills.
- 3) This proposed model fulfil the lack of sleekness in the terms of accuracy and strength and as well as portability to carry the machine for long term distances.
- 4) Aluminium pipe bending i.e. Non Ferrous pipe bending can be done by just changing the metallic interconnected shafts with Derlon interconnected shafts.
- 5) Metallic circular pipe bending and rectangular pipe bending into the form of cylindrical shape bending can also be possible with the help of this structural model.
- 6) Sheet metal bending of length ranging from 400 – 500 mm with a thickness of 5 – 6 mm is also possible, henceforth concluding the three different purpose of Metal Bender Machine (4,5,6)

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# Development of the Experiment to Predict Conversion in Batch Reactor Using Virtual Laboratory and Artificial Neural Network

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**Abstract:** This paper deals with development of laboratory experiment using virtual laboratory and open source artificial neural network software at an undergraduate level course. The study includes the use of virtual lab to generate data for the batch chemical reaction engineering laboratory and subsequently generated data were used to train artificial neural network (ANN) model. The purpose of this laboratory work is to give students exposure to handle complex problem and enhance their problem solving skills and to expose them to advance computation tools. The problem was designed to predict the conversion of reaction between sodium hydroxide and ethyl acetate carried out in batch mode. The vlab was used to generate data without actually performing experiments, which is normally quite time consuming exercise. The data generated are then used to train ANN model using easily accessible neural network based software. This laboratory work has been in use at the Department of Chemical Engineering for last four years. The feedback and questionnaire have been obtained from the students from last two academic years. The results of questionnaire have been quite encouraging. The ability of students to handle complex engineering problems tends to increase with the use of advance computational tools.

**Keywords:** Vlab, ANN model, computational tools, problem solving skills, conversion

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## 1. INTRODUCTION

The experience of the author at the Department of Chemical Engineering, S.V National Institute of Technology, Surat, India suggests that the limited exposure to lack new concepts is major hurdle for students willingness to learn techniques and skills. Furthermore, the author found from his personal experience that students need careful guidance and tutoring in the beginning to promote self learning. To encourage self learning, new concepts can be thought by devoting extra time in tutorial, theory as well as laboratory sessions. The softwares based on different numerical techniques are extensively used for problem solving in recent years in many courses of chemical engineering (Shacham and Cutlip, 1999). The use of computational tools is advantageous on account of their high accuracy, easy adaptation, high efficiency and cost-effectiveness (Li and Huang, 2017). Further, The use of computational and process simulation tools has been regarded as quite essential for employability of chemical engineering graduates (Belton, 2016; Grant and Dickson, 2006; Lewin et al., 2002). Shacham and Cutlip (1999) compared different softwares such as Excel, MAPLE, MATHCAD, MATLAB, MATHEMATICA and POLYMATH to solve ten representative problems pertaining to Chemical Engineering courses. The use of software such as MATLAB in chemical engineering curricula has been attracting widespread interest during recent decade (Li and Huang, 2017). The use of virtual and e-lab has been

regarded as effective tools to enhance student's learning (Angel, 2015; Gautam et al., 2016). Further, the generation of large and complex dataset during study of engineered process is quite common. The extraction of meaningful information from such large datasets is very challenging task and requires knowledge of advanced data mining techniques.

The available free tools were utilized to improve student's interest to learn new techniques and methods to solve complex engineering problems. Here in this study we employed the virtual lab (in this study referred to as vlab) to design new laboratory work to enhance learning experience of the students using advance tools. This virtual lab is easily accessible at <http://vlab.co.in/>, which is an Initiative of Ministry of Human Resource Development (MHRD), Government of India, under the National Mission on Education through ICT to allow Students to learn and increase their knowledge. The major objectives of this initiative are to provide remote-access to Labs in various disciplines of Science and Engineering, inspire students to conduct experiments online without consuming actual resources, availing the different tools for learning and self evaluation through web resources, demonstration videos, video lectures. This is great initiative by MHRD, Government of India, for vast country like India, where accessibility to the advance instruments and facilities is always limited. Thus, such medium provide platform to

share costly resources effectively through the use of internet and computer technologies.

To handle data effectively vlab has been linked with artificial neural network, wherein data generated by the vlab was used in the freely available neural network programme known as Multiple Back Propagation software (MBP software), which is available at <http://mbp.sourceforge.net/> (Lopes and Ribeiro, 2011). The purpose of this laboratory work proposed in this study is to enhance students learning experience, enhance problem solving skills with advanced computational tools. In this work, Virtual laboratory was used to generate data. The problem deals with prediction of the conversion of reaction between sodium hydroxide and ethyl acetate carried out in batch mode. These data are then fed to neural network to develop ANN model by MBP software. The developed ANN model was then utilized to predict the conversion for the set of the unknown input variables.

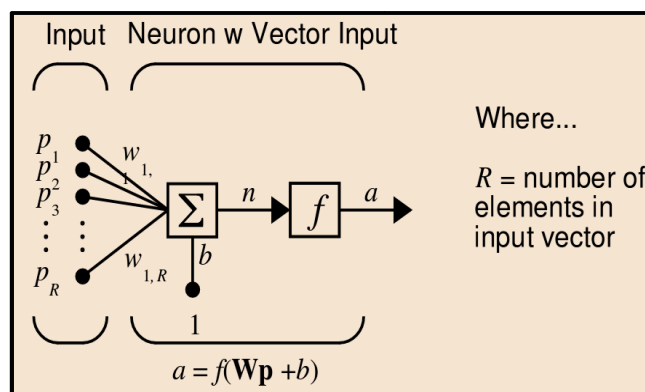
## 2. METHODOLOGY

The proposed experiment was conducted as a part of undergraduate laboratory work in the Chemical Reaction Engineering course at the Department of Chemical Engineering, S.V National Institute of Technology, Surat, India. The use of vlab is self explanatory in nature and every student can be able to perform experiment easily after reading instructions. However, detailed instructions to use virtual laboratories at <http://vlab.co.in/> have been provided with the help of Teaching Assistant and Research Scholars engaged in the laboratory work in the CAD lab of the Department. The laboratory was conducted in the group of 3-4 students. The vlab used was developed by the Department of Chemical Engineering, NIT-Surthkal, which is available at the <http://uorepc-nitk.vlabs.ac.in/exp7/index.html>. This laboratory is about the study of kinetic of the reaction performed in the batch mode, which was used to predict conversion between sodium hydroxide and ethyl acetate. The author also gave live tutorial on how to use Multiple Back Propagation software to develop ANN model. The step by step instructions were provided on how to generate data and prepare data file to be used in the MBP. Tutorial based on the screenshots is also available at <http://mbp.sourceforge.net/tutorial.html>.

### 2.1 Artificial Neural Network:

Artificial Neural Network is powerful information processing tool mimicking function of biological neuron network. They consist of interconnected neurons connected by synapses or links, which are characterized by synaptic weights. It mainly consists of three layers: the input layer, the hidden layer and the output layer. Each layer is connected to other layer by the neurons through synaptic links. The information from one layer to another layer is transferred by these neurons through transfer functions. The

basic mechanism by which ANN function is based on the four major requirements viz., a) inputs are processed by the processing neurons, b) inputs are passed to subsequent layers through neurons connections, c) each neuron connection is characterized by the weight, and the transmitted and processed input from each neuron is product of respective input and its weight and d) transmitted input pass through an activation function of neuron to calculate output ((Hagan et al. 1995). Fig. 1 shows a typical neuron structure where each input (p) coming from another neurons are multiplied by their respective weights ( $w_{1,i}$ ), and then summed up (n), which is then passed through appropriate transfer function to get the output (a) (Demuth and Beale, 2002).



**Fig. 1. A typical structure of neuron (Adopted from Demuth and Beale, 2002)**

In this category, feed forward neural networks also known as Multilayer perceptrons (MLPs) are the most popular type of ANNs. In this work performance of neural network was evaluated by measuring the root mean square error (RMSE) between values predicted by the ANN model to experimental data (Nazghelichia et al., 2011) as follows:

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (y_{pi} - y_{ti})^2} \quad (1)$$

## 3. RESULTS AND DISCUSSIONS:

The data to be generated based by vlab using the design of experiment with different levels of factors are shown in the Table I. In this work three input parameters viz., concentration of ethyl acetate ( $C_{AS}$ ), concentration of NaOH ( $C_{BS}$ ), and Temperature (T) have been selected as input variables (Factors) to study their influence on the conversion of ethyl acetate ( $X_E$ ), which was selected as output variable (Response). The initial molar ratio of reactants and the reactor volume was set to unity for all the experiments. The Table II shows the experiments to be conducted by the vlab based on the design of experiment shown in the Table I. The conducting virtual experiments

with different settings on vlab are quite easy with user instructions.

**TABLE I: Input parameters (factors) and levels used in the experimental design.**

Factors		Level 1	Level 2	Level 3
A Concentration of Ethyl acetate (N)	$C_{AS}$	0.02	0.04	0.06
B Concentration of NaOH (N)	$C_{BS}$	0.02	0.04	0.06
C Temperature ( $^{\circ}$ C)	N	30	40	60

The operating parameters as dictated by the Table I can be easily set. The reaction between NaOH and Ethyl Acetate is second order and fast reaction at room temperature. Hence, all the experiments were run for 2 min on vlab to capture proper trend of effects of parameters on conversion of Ethyl Acetate. The results obtained by vlab are tabulated in the Table II. Total twenty seven experiments were performed as per DOE. In addition seven data were arbitrarily selected, which were not used for training of network and labelled as trial data. These additional data were used to validate, verify and evaluate predictive capability of ANN model, which was developed based on the data generated by the vlab.

**TABLE II: Set of training and testing data used for neural network training based on the design of experiment.**

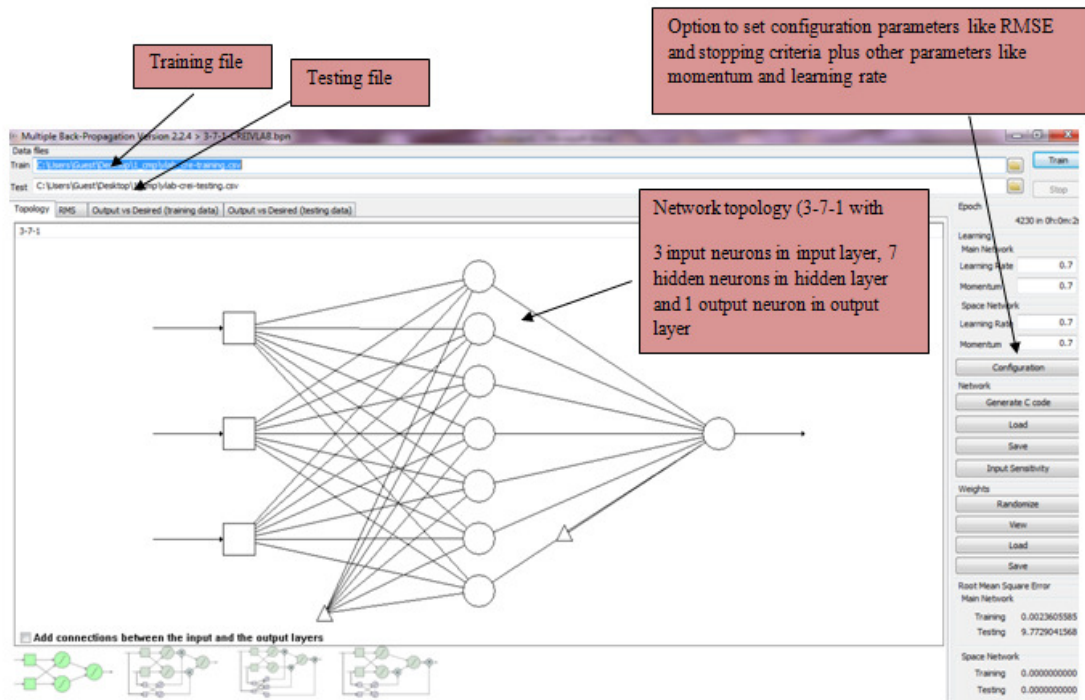
Sr. No.	Input Parameters (Factors)			Output (Response)
	$C_{As}$ (A) (M)	$C_{Bs}$ (B) (M)	T (C) ( $^{\circ}$ C)	Conversion of Ethyl Acetate (X)
Training Data				
1	0.06	0.02	30	0.9855
2	0.06	0.06	30	0.9851
3	0.04	0.06	30	0.9778
4	0.02	0.02	30	0.9577
5	0.02	0.04	40	0.9760
6	0.06	0.04	40	0.9915
7	0.04	0.04	50	0.9926
8	0.06	0.04	50	0.9950
9	0.06	0.06	40	0.9915
10	0.06	0.04	30	0.9852
11	0.06	0.02	50	0.9950
12	0.04	0.02	30	0.9782
13	0.04	0.06	40	0.9873
14	0.06	0.06	50	0.9950
15	0.02	0.04	50	0.9863
16	0.02	0.02	50	0.9853
17	0.04	0.04	40	0.9874
18	0.02	0.02	40	0.9754
19	0.02	0.04	30	0.9578
20	0.02	0.06	50	0.9851
Testing Data				
21	0.02	0.06	40	0.9749
22	0.02	0.06	30	0.9565

23	0.06	0.02	40	0.9916
24	0.04	0.06	50	0.9926
25	0.04	0.02	50	0.9924
26	0.04	0.04	30	0.9779
27	0.04	0.02	40	0.9873
Trial Data				
28	0.03	0.06	30	0.0000
29	0.03	0.06	40	0.0000
30	0.03	0.06	50	0.0000
31	0.025	0.05	30	0.0000
32	0.025	0.05	40	0.0000
33	0.025	0.05	50	0.0000

### 3.1 Results obtained by ANN using MBP software

The Fig. 2 shows the topology of ANN as produced by MBP software. Different elements have been highlighted in the Fig. 2. The Table III shows the trained networks and criteria to select the developed ANN model. All the

networks have been trained for 4000 epochs and the target for network in terms of Root Mean Square (RMS) error was set at 0.0001. The main element of selection of network topology is to decide number of hidden neurons in hidden layer. Thus, we trained different ANN models.



**Fig. 2. Neural network topology (3-7-1) selected after training**

with different number of hidden neurons as number of neuron in the input layer is fixed at 3 (which is equal to number of input variables) and number of neurons in output layer is fixed at one (which is equal to number of responses). The results are tabulated in the Table III. It is

clear from the result that the network 3-7-1 with seven hidden neurons obtained lowest RMS in 4000 epochs. Hence, ANN model with seven hidden neurons (3-7-1) was selected for further analysis. The Figure 5 shows the result obtained by trained network 3-7-1. The selected network

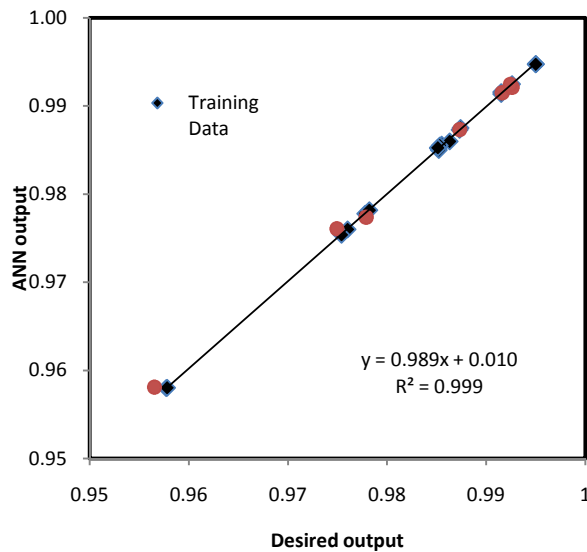
was able to predict the desired output with quite good accuracy as is evident from very high value of correlation

coefficient ( $R^2 = 0.999$ ) as shown in the Figure 5. Thus, proves the effectiveness of the trained network.

**TABLE III: Network topology selection based on RMSE.**

Network types	MLP 3-3-1	MLP 3-4-1	MLP 3-5-1	MLP 3-6-1	<b>MLP 3-7-1</b>	MLP 3-8-1
Root Mean Square Error (RMSE)	0.00469	0.00327	0.00353	0.00250	<b>0.00236</b>	0.00242

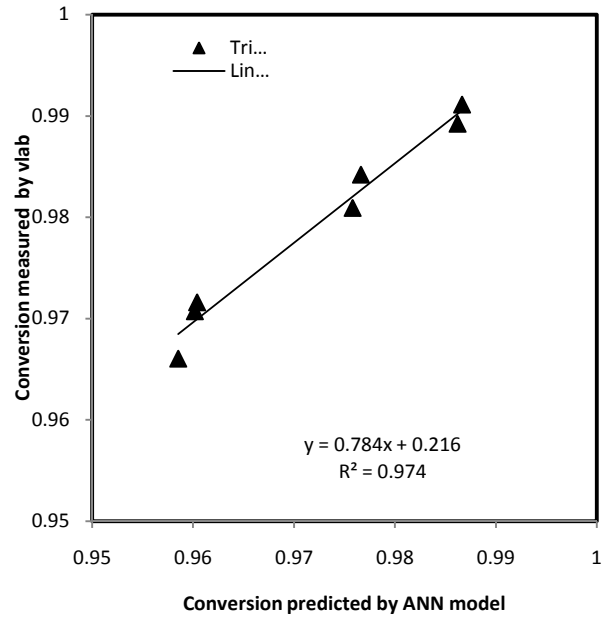
This trained and developed ANN model was then used to predict the conversion for the given set of unknown inputs labelled as trial data (see Table II) to test validity and predictive capability of trained network. The trial data have been selected arbitrarily and contain data not used in training and testing data. The target value for trial data were set to zero and clubbed with testing data as suggested by the developers of the software in Table 2. A scatter plot (Fig. 3) clearly shows that the conversion predicted by trained networks compares well with the target values, which is evident from very high value ( $R^2 = 0.999$ ) of correlation coefficient.



**Fig. 3. Experimental vs. predicted response by ANN model for training and testing data**

### 3.2 Validation of ANN by confirmation experiments

The Fig. 4 shows the data predicted by the developed ANN model (3-7-1). It is clearly seen from the Fig. 4 that developed ANN model can able to predict the results for unknown inputs with good accuracy ( $R^2 = 0.974$ ). In almost all the cases the percentage error between predicted values and experimentally measured values (by vlab) was found to be less than 1 %.



**Fig. 4. Experimental vs. predicted response by ANN model for trial data**

## 4. ANALYSIS OF STUDENT'S RESPONSE FROM QUESTIONNAIRE:

The Table IV shows the questionnaire prepared to evaluate the feedback from the students. The total ten questions were prepared to study effectiveness and usefulness of the designed lab from the point of view of the students. The students were asked to voluntarily give feedback by answering the questionnaire. The main objective of this survey was to evaluate the students' opinion on the designed laboratory and to find how this approach helps them understand difficult engineering problems effectively using advanced computation tools. Further goal of this survey was to understand how this approach helps students learn new concepts and how to make it more effective. We asked third year undergraduate students from two different academic years (2015-2016 and 2016-2017) to participate in this survey. Total 114 students responded to the survey voluntarily. Overall the results of survey were quite encouraging with positive response to the questionnaire.

**TABLE IV: Results of the questionnaire on the laboratory of vlab with MBP for academic year 2015-2016, 2026-2017 with total respondents n =114. Grading of the questionnaire is as: 1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree.**

Sr. No.	Question	1	2	3	4	5
1	The training meets objectives specified by the instructor					
2	The selection of laboratory is good and relevant to your course.					
3	Your engagement/involvement in the laboratory session is highly fruitful.					
4	The laboratory session resolve your questions/queries effectively.					
5	The laboratory session helped you deal with complex engineering problem easily with artificial neural network					
6	The laboratory session gives you enough scope for self learning.					
7	Strongly recommended that this laboratory session should be retained as part of the course.					
8	Strongly recommend addition of more such laboratory sessions based on your experience in this laboratory session.					
9	Overall quality of laboratory session is good.					

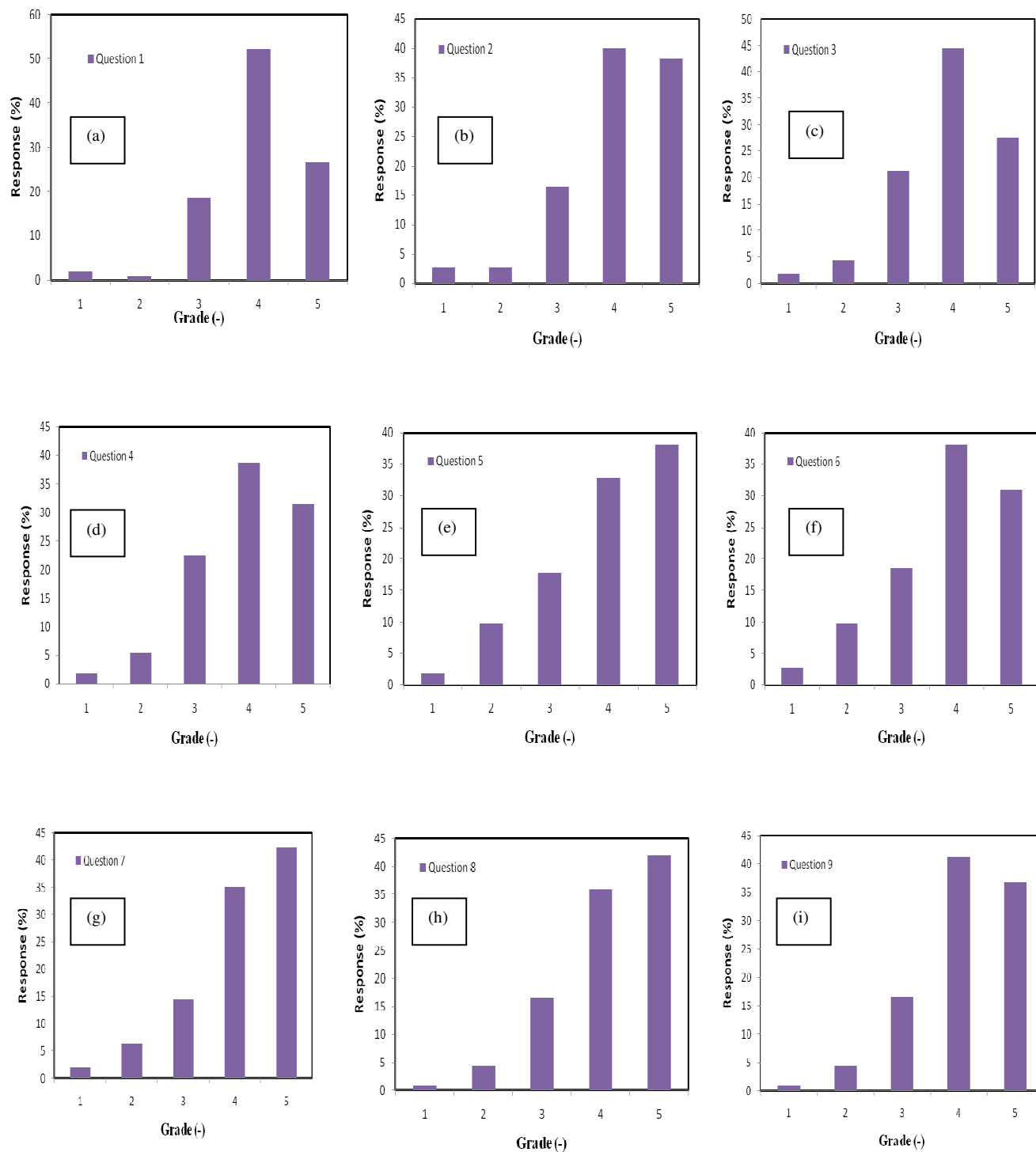
The response to each question in the questionnaire represented in the Table IV is shown in the Fig. 5. The majority of the students (78.8 %) agreed that laboratory assignments meet the objective specified in the beginning in response to question 1, whereas 18.6 % students were neutral with only 2.7 % did not agree with the question. The majority of the students (78.2 %) find this work highly relevant with good selection of laboratory work (question 2), with vote to 5 increased from 26.5 % to impressive 38.2 %. The 44.6 % students agree that their engagement and their experience during this session were good (question 3). When asked about how well their queries and doubts were resolved (question 4)? Students seem to be little divided with 7.2% responded in favour of 1 and 2, while 70.2 % voted in favour of 4 and 5. Further, the disagreement level increased to 11.5 % (for question 5), but 70.8 % still agreed that this lab help them deals with complex problems using artificial neural network. In all above cases the neutral students remain in the range of 16- 24 %. We observed similar response to question 6 with 12.4 % disagreed with preposition. The interaction with students suggested that they find it tough to spare extra time and find it difficult to understand concepts without help. Hence, even though work is good many find it hard to carry on due to fast paced Undergraduate curriculum. The response to the question 7 and 8 is very positive with 77.8 % students recommended (with more than 40 % are strongly recommending) such laboratory session and in favour of introducing more such sessions. Further, students appreciated the overall quality of laboratory (question 9) to be good with majority voted for 4 and 5. Hence, the objectives of the designed

laboratory seem to be largely met as can be evident from the student's response to the questionnaire.

## 5. CONCLUSIONS

The vlab has been linked with artificial neural network to predict the conversion of ethyl acetate for different operating conditions. The Virtual laboratory was found to be quite effective in generating large data as it facilitate performance of large number of experiments just by click of mouse and at the same time give experience of the real time laboratory experiments. The capabilities of virtual laboratory have been demonstrated in this work. The data generated by vlab have been employed for training of the neural network. The developed ANN model was tested for its predictive power by predicting the conversion for unknown input conditions. The predicted values of conversion by the ANN were compared with conversion measured by virtual lab. Thus, students were exposed to handle complex problem by using advance computation tools. The results of questionnaire obtained from the students of two different academic years were found to be very encouraging. With majority of students found this experiment highly useful and productive. The majority of the students responded positively to the all the questions. We can conclude that the ability of students to handle complex engineering problems tends to increase with the use of advance computational tools. This innovative exposure greatly benefited and motivated students to acquire and equip themselves with new skills. The author recommends more such laboratory sessions to enhance students learning and problem solving skills.





**Fig. 5. Responses to the Questions presented in the Table 4.**

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Development, Government of India for creating vlab under the National Mission on Education through ICT and provide free access to <http://vlab.co.in/>. Author also acknowledge the developers of MBP software (available at <http://mbp.sourceforge.net/index.html>) to provide free access to software. Further, author wish to acknowledge



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SECTION – VII  
ADVANCE MANUFACTURING SYSTEM-LEAN,  
SIX SIGMA, AGILE QUICK RESPONSE  
MANUFACTURING

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# Study on World Class Time Management

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**Abstract:** Time Management is one of important aspect in every organization. For perfect time management several important facts and possibility should be considered. Basic of all management theories have been fulfilling with planning, controlling, organizing, directing, coordinating, etc. In this article we study in detail for better time management no. of other parameters are play vital role such as perspective management, operations management, waste management, supply chain management, strategy management etc. Discuss here used of proper technology for improving quality, quantity, reducing time for any processes.

**Keywords:** Time Management, Quality Management

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## 1. INTRODUCTION

The world class time management is based on how we manage use of all utilities and accessories effectively in right area to enhance our main object with great accuracy in a specific way. Here we dealt with number of case related to world class time management concept. All following cases are good example of it.

- Dharmasthala Shri Manjunatheshwara temple,
- Kalinga Institute of Social Science,
- Shirdi Shri Sai baba Sansthan
- ISKCON Yatra,
- Dabbewala of Mumbai.

While doing this study we will understand meaning of “TIME IS MONEY”. Above mentioned all examples have running with successful management with using user friendly technology. It is very important to know how they manage millions of people daily and how they handled all devotees within few hours. These researches provide knowledge about not only time management but also know about perspective management, operations management, waste management, controlling human activities. It show standard phenomenon of how managing all managerial functions and concentrating only on time and satisfaction of people by providing food.

## 2. CASE STUDY

### 2.1 Dharmasthala Shri Manjunatheshwara Temple

It is India's one of best management to handled 25000 to 50000 people a day. It's like to manage 400 wedding parties at a time. They make effort on waste management, perspective management, waste management, water management, and especially time management.

There is chief administrator namely Dr. Hedge, he is responsible and full time occupation keeping tradition as to maintained & proceed legacy of management from 800 year old. Feeding foods to millions of people with great respect and satisfy devotee. They have 9500 sq. ft. area of kitchen like 4 basketball court. Have 9 bay lines. Each bay line 6.5 meters gap and each bay line contain nearly 400 devotees at a time. They have been work very effectively to feed and clean area within only 13 minutes. This is because of accurate time management to maintained queue. In such way that they have manage to doing mega services since last 800 years.

Always have a meeting with core committee with chief administrator for planning, controlling, organizing, and many other aspects of management and prepare for festival namely Lakshadipostava. At the festival more than 100000 devotees have serve by Annapoorna kitchen daily in a 5 days festival. Within less time have to cook and feed food to huge crowd of devotees.

Every manager has responsibility to check all equipment and raw material for cooking from begin of work. They are ready for massive amount of cooking within few hours. As per preparation they cook huge quantity of rice like 6500 to 8000 kilos of rice in a day following big equipment's and utilities. Around 25 people are for chopping vegetables will be needed to cook. They use spices in mega scale in measuring equipment to maintained quality and taste by quality management. Nearly 45 kg sambhar spices to make 3000 lit. Sambhar. They need coconut and milk of coconut and vegetables in large quantity. For that purpose they maintained large no. of tree of coconut from last many decades and planted 1 million of trees. They have own dairy farm with 125 cattle.

The process water by making rice in kitchen is in big quantity nearly 3000 to 5000 liters a day that are passed

from kitchen to farm by piping. We know that not easy to disposal of process water. That water contains heavy grain is an important diet for cows. Resulting cows produced 3500 liters of milk a day. Quantity of milk again used in kitchen. They use leaf plates to serve food because leaf plates easily dispose and it is eco-friendly. No need to clean and no used of water. And also it helps to speed up services need only 13 minutes to seat, feed, & clean up. That is why there time is very important parameter.

When 1st row of people have seated, 2nd row also start seated and serve, and by the time 7th row is seated, it's time to clean up 1st row. In this way high speed is necessary to serve thousands of people. Devotees don't feel that there in queue because within 10 minutes devotees have been serving. Annapurna kitchen has daily produce 1000 to 3000 kg organic waste and also from hectic chopping section of kitchen and even leaf plates have been used for serving food. All waste is collected and transport to garbage stack started composting. It is an environment friendly process to recycle such huge quantity of organic waste. Every year they produce 130000 kg compost and its back to tree for farming.

In this way there is perfect time management; waste management and perspective management are effectively performed.

## **2.2 Kalinga Institute of Social Science**

This institute located at Orissa, Bhubaneswar, India and it is also largest tribal residential school in world. School campus is around 80 acres area. School has more than 25000 children for education among them is Olympians, national level players, doctors, lawyer and learn achieve their goal.

The school has always maintained food management, time management, to serve and satisfy 25000 poor children with providing 50000 meals a day within accurate time. School has 3 to 4 batches with each batch containing 8000 children in a day. That is why there is huge importance to time management to dealt/satisfy poor children by meal.

They have India's one of biggest mega kitchen operating with 7 day and produce 50000 meal a day. This quantity of food is enough to fulfill requirement of entire Indian Navy. Start with breakfast, lunch, dinner. Breakfast is important meal of day. For breakfast used 1000kg cornflakes, 5000 liters milk consume in single breakfast. This is enough to feed a 4 family nearly 20 years. Every student has been served 40gm cornflake and 200 ml milk in each ball and sometime 1 banana. Student has serve meal 3 to 4 batches from several locations in campus of school for maintained queue. Making meal in such big quantity and serve to students they have been successfully manage task every day within few hour.

For reducing time of cooking of meal used steam boiler. Have 8 vessels containing 680 liters each to cook vegetables and 20 vessels have been cook 380 liters each to boil rice are supported with 4 big boilers running by diesel which generates steam. They follow engineering and management to maintained time accuracy. Serve 4000kg rice have been enough to feed average rural Indian for over 50 years. 1000 students involve in work of management to serve food to 25000 students while working they all get knowledge of basic management and team work. For that 230 girls are there pre assign for work to 2400 kg vegetables chop and grade. Kitchen work is only for 40 min for them and back to lectures or respective work.

Management is divided in experience teams to handled quality and quantity of food which is in large scale with few hours. Ingredients proportion is main factors to maintain taste in such large scale production. Quality management is play vital role to keep SOP (Standard Operating Procedure) and ratio of every item. Using steam cooking process to cook 100 kg rice in 7 to 8 minutes and 150 kg required 17 to 18 minutes.

They have to maintained meal before 12 o'clock for students and serve meal within few minutes. There will be no delay because of proper time management. Student volunteers also there for help to serve meal. School having 24000 sq. ft dining hall like small colony more than 25 two bedroom houses are place in one space. This space is not enough to accumulate 25000 students at a time of feeding. Because they have 3 to 4 batches, each batch contain nearly 8000 students and it needed 40 minutes to 2 hours to feed, clean and cook again.

Kalinga institute provided Dietitian, Quality In-charge, health consultant and team of doctors. School mega kitchen provided veg as well as non-veg food like chicken and fish. It requires 2400kg chicken and fish every week and 75000 eggs every month. Institute has specific water management and waste management like RO (Reverse Osmosis) plant for generation of clean water and concentrate used of renewable energy system.

For this purpose using solar energy to boil water nearly 10000 liter per day directly use in kitchen to cook lunch and dinner. By using such technology minimize time and reduce LPG consumption. Organic Waste generated in kitchen transfer to bio gas plant. Bio gas plant capacity is 1000kg per day. Organic waste is shredded and converted into slurry with adding water. Every day bio gas plant has produce 75 cubic meter gas used in kitchen. Kitchen staff plays important role 25000 meal at a time less than 3 hours. Board meeting decided for add, eliminate, every single item in process. Material management team manages high quantity of raw material. Needed 50000kg rice, ingredients and vegetables. Checking, maintaining raw material and strictly followed physical audit by them.

### 2.3 Shirdi Sai Baba Santhan

Shirdi sai baba santhan is India's one of most famous destination for devotees. In Shirdi 70000 to 80000 people visit a day. They have been followed great management and technology to handled queue. Shirdi sansthan have one of biggest kitchen in world to serve food.

The world largest solar panel installed in Shirdi sansthan large array of concave mirror that collect sunlight for hot water and steam for cooking process. Solar system has 73 dish and around 16 sq. m which Contain 380 mirrors. They distribute power of sun in 4 different sections. Dishes in series over kitchen (Prasadalaya) connected with receiver and water source. With using solar energy make 3500kg steam. So kitchen run by effective use of solar energy and it is installed in 2009 at this stage its world biggest solar system. With used of solar energy high speed cooking have perform in kitchen for large no. of devotees with in very less time. It helps to accurate time management.

Team of quality management is responsible for scale up material like vegetables, spices etc., making meal for devotees. They have 6 big vessels contain 100kg each vegetables and large size grinder and mill for making flour. Roti machine make 5000 to 6000 roti's with high speed machines using solar energy. Means that machine make 2000 roti's in only one hour. To manage crowd of devotees has 5 such machine to make roti nearly 30000 within only 3 hour and 120 workers for chopping vegetables. This speed is necessary for better time management and to handle queue.

Work start from 7 a.m. to 10 a.m. very busy to produce such big quantity meal and serve exactly 10 a.m. to 35000 people. That is why their time is so valuable. Seating arrangement of devotees is 3600 at a time approximately 40000 people in regular day and 80000 to 100000 people in festival visits in Shirdi. It is really challenging to handle not only people but also quality, quantity, taste and time precision. In addition, with used of solar energy Shirdisansthan have save Rs. 2900000 per year. In Shirdi sansthan we can see gives importance to both management as well as technology and one of biggest spiritual center using efficient technology (by using non -conventional energy system) to help the environment and user friendly.

### 2.4 ISKCON Yatra

ISKCON Yatra (Journey) of lots of people one place to another place along to meet of Lord Shri Krishna over India. They followed principles of management successfully to complete and satisfaction of people (Devotees). This is spiritual journey of 11 day on kartik mas. People came across different region of India for this journey and more than 100 of buses of devotees involved. Also many national and international people participate in

journey at Vrindavan. Journey has start from Vrindavan (for 6 day) to govardhan (5 day).

Management is important factor in the journey because it is one place to another which is very difficult. It is very important to make sure all aspect of ISKCON Yatra is ready on time at every place. They take care about every single item related to traveling, making food, equipment's that are unloading and loading at each place.

As we know about principle of management like planning, controlling, organizing, scheduling, directing, coordinating etc. we will see proper used of basic principles in this journey. They handle and installed stall (Mandap), Setup of Mega Kitchen, and instruments overnight means within few hours. Every place maintained kitchen on time to feed or serve food to thousands of devotees. Management has concentrated on basic requirement of devotees at every place. Core team of management has following brain storming and group discussion for prepared smooth and comfortable journey of participants. Their Mega kitchen is produce 2 meals a day for more than 5000 participants. Just like to prepare for Indian army.

For making such high range of meal have maintained big size equipment's and Equipment size is nearly 20 ton. So they prepare for transportation arrangement. Kitchen equipment contain vessels having capacity 100 kg that have been cook 2 meals for over 5000 people approximately 110000 meal. Mega kitchen specifications are 5000 sq. ft area, 1500 sq. ft Roti and Dosa section. 5000 sq. ft vegetables are chopping.

Important fact is that there are engineers of top university in management to handle such big responsibility efficiently. They used proper blue print of process specification related to journey. Their expert made 100 % eco-friendly kitchen every time in journey. So here in this process we can understand use of engineering and management to complete their work and satisfy devotees with food.

In their mega kitchen they make 600 ft track and trolley system to move heavy size vessel and food from place of kitchen. To pull or lift up big vessels they have arrange crane and pulley system for heavy weight task lighter & safer to minimize time of processing food. This all system they easily join and dismantle for consuming time at every place of journey. During journey need 1000kg vegetables, 1500kg potatoes, 1000kg carrots, handled by their material management team, 3500kg other vegetables. They follow one important criterion which tries to use milk, ghee, and all cows (milk product) from non-violence or ahinsa source. It means that cows are protected for life. Start their work at 3.30 a.m. early morning to feed food (1st meal) within 3 hours at Vrindavan and serve at 6 a.m. By quality

management set standard to cut vegetables supported 150 volunteer to cut and slice.

Here only time is an important factor for maintaining smooth services and serve food to people on time. This is because of proper time management And for that they have prepare 8 counters at different point to manage crowd of people (devotees). After serving 1st meal they prepare to make 5000 meals which will is served at lunch. Quality management team is using different measuring instruments and control devices for accurate quantity of ingredients for large scale. All calibration is documented and listed for future references.

### **2.5 Dabbewala of Bombay**

Operation of Bombay Dabbewala is great example of management. They have followed six sigma theory of operation management. Work is design in such way that coding, encoding, decoding, collection, transportation or logistics. Also we can say that this is one of best example of team work.

They have transport lunch boxes in different area in Bombay. This is very busy and complex management process and delivering 150000 lunch boxes from home to costumer daily last so many years regularly with negligible error. It is very effective delivery process in any atmospheric conditions by group of 5000 individuals organized in the form of co-operation.

Forbes journal has had an article on Dabbewala of Bombay. Top management institute has followed theory of Dabbewala of Bombay for teaching purpose.

In this paper we will learn world class time management of Dabbewala of Bombay. They collect, transport & delivery of lunch boxes from home to office location in early morning and collect empty lunch boxes in evening. This system is started at 1890. The system has been operational for 120 years without any interruption. As of 2005, Dabbewala of Bombay have been handled 300000 transactions a day nearly 150000 lunch boxes and employed 5000 people and earn Rs. 360 million every year. They reported less than 6 errors in 13 million transactions. 5000 people in the system. Each of them assigned up to 30 customers and having fixe route and area are pre-assigned. Each Dabbewala has maintained 30 lunch boxes and visit made in 8.30 a.m. to 9.00 a.m. Each Dabbewala has carry 100kg load by their head and walk 2.5km between 8.30 a.m. to 5 p.m. every day. After receiving 30 lunch boxes, he looks for railway station to

transportation. Their 8 Dabbewala organized as a team and operates. They have 120 groups in system. This group is responsible for entire operations & supply chain management.

Dabbewala of Bombay has name in Guinness book of world record. And they have also world record in best time management. We can learn lot of management concepts from it and because of this Bombay Dabbewala subject included in Graduate School of Journalism University of California, Barkley. And also they invited to attend marriage of Hon. Prince Charles of England on April 9, 2005. It is Register in Ripley's "believe it or not". They maintain their legacy more than 100 year and world class time management process. Documented in BBC, UTV, MTV, ZEE TV, CNBC TV 18, CNN, SONY TV, NDTV.

### **3. CONCLUSION**

As discuss throughout the paper, learn different aspects of management of time. Every example of our paper has main objective to fulfill satisfaction of human being and development of civilization from ancient time. Few cases have been adopted innovation based strategy to do accurate, economic and minimize error of management processes. This paper will give knowledge about used of environment friendly traditional techniques, optimization of resource, carefully handling utilities, effective used of man power. These examples are great source of inspiration of technology based time management as well as legacy (Traditional) based time management and scientific method of time management (Coding-Decoding)

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# Lean Manufacturing Implementation Using VSM: Case of Junction Box Post-Processing Phase

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**Abstract:** In today's world, the quality of the product alongwith timely receipt of products is the key to business development. 5S, Value Stream Mapping, Kaizen, Kanban, Just In Time tools were studied for implementation of Lean Manufacturing to identify & eliminate non value added activities in the production process leading to reduction of lead time, for a discrete manufacturing company, manufacturing Junction Box in India. After detailed analysis, VSM & Kaizen technique were successfully implemented in post production processes of Junction Box manufacturing with reduction in lead time from 30.33 days to 21.14days.**Keywords:** VSM, Current state map, Future state map, Lead Time, Takt Time.

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## 4. INTRODUCTION

Value Stream Mapping is a powerful tool used in Lean Manufacturing study. VSM is the simple process of directly observing the “flow of information & material” as they occur & summarizing them visually. It is a tool to analyze process flows from a systems perspective & to document the performance of the process. A Value Stream involves all of the steps, both value added & non-value added, required to bring a product or service through the process steps. VSM is a visual tool used to help see the hidden waste – & sources of waste – in the value stream. A Current State Map (CSM) is drawn by a cross-functional, multi-disciplined team to document how things actually operate. Then a Future State Map (FSM) is developed to design a lean process flow through the elimination of the root causes of wastes & non-value added activities & through process improvements. As with the theories of waste identification & elimination, Lean Manufacturing principles, VSM has its roots in Toyota Production System (TPS).

In industry where implementation of VSM techniques is yet to be implemented is discrete manufacturing environment. One such discrete manufacturing environment is the post-processing of Junction Box, where the absence of any VSM increases lead time, & thereby delaying the supply to target customers. The current study focuses on applying VSM to the Junction Box Industry & reduction in lead time.

## 5. LITERATURE REVIEW

J. Dinesh et. al Introduced VSM is a useful tool for process analysis & improvement by identifying & eliminating time spent on non-value-added activities. By using VSM the process time & value added & nonvalue added activities are identified. Lead time is reduced by improvement made in

the pump industry. VSM have been proven to be a greatly useful tool to eliminate some waste in a cycle & find there are more waste for you to eliminate in next cycle, during which lean becomes a habit or culture.

G Saranya, S.B. Nithyananth have implemented VSM. In This paper they compares the current state & future state of a manufacturing firm & witnessed 20 % reduction in TAKT time, 22.5 % reduction in processing time, 4.8 % reduction in lead time, 20 % improvement in production, 9 % improvement in machine utilization, 7% improvement in man power utilization, objective improvement in workers skill level, & no change in the product & semi finished product inventory level.

R.M. Belokar reported the application of VSM in an automobile industry where they achieved nearly 67% improvement in cycle time by improvement in value adding activities.

Ramnath B.V. et al described using VSM as a main tool. The focus of the lean manufacturing approach is on cost reduction by eliminating Non- Value added activities; identify sources of waste & to identify lean tools for reducing the waste. To eliminate the wastes found from the current state map, Kanban system was suggested for pre machining section & single piece flow concept is suggested for Machining section.

Maria Elena Nenni1, et. al. (2014), demonstrated the positive effect of a Lean Management (LM) approach, in a pharmaceutical company, subject to critical market issues, by using VSM tool outcomes, with decrease in non value added activities, Total cycle time reduction, Work force



reduction, Work in process reduction, Reduction of shop floor area & floor space.

According to Taho Yang Yiyo Kag suggested & implemented lean production system for fishing net manufacturing, using the various lean tools & simulation method & make to order process are apply for the regular shipment. VSM tool was used to predict future state map & increase service level & reduce lead time, also provided guide lines for the implementation of VSM in any manufacturing industry successfully & cost reduction by elimination of waste.

According to Jafri Mohd et. al. used production line analysis through VSM for color industry, thereby identified & eliminated waste by using team formation, product selection, conceptual design, & time frame formulation through TAKT time calculation. Some lean techniques were used to reduce change over time by 5s, decreased lead time from 8.5 days to 6 days & value aided time decreased from 68 minutes to 37 minutes.

Rajenthirakumar & R.G. Shankar reported a noticeable reduction in cycle time increase in cycle efficiency with an application of VSM. The production flow was optimized, thus minimizing several non-value added activities/times such as bottleneck time, waiting time, material h&ling time, etc.

K. P. Paranitharan provided a useful platform for research in implementation of lean tools in any mfg unit. Their results showed a significant improvement in productivity, reduction of production lead time & reduction in inventory. These were achieved by layout modification & balance to TAKT time.

Praveen Saraswat et al. applied VSM on bearing industry for reducing the work in process & inventory & lead time. This research study described how the value mapping graphically visualized the flow of material & flow of information from customer order to finish product. With this approach (VSM) wastes in the company can be reduced. Reduced work in process inventory & lead time.

Rumbidzayi Muvunzi et. al introduced using the VSM, Productivity increased from 20, 220 tiles per month to 28, 350 tiles per month, in the tile manufacturing industry. There was reduction of defects from 245 defective tiles per day to 10 defects thus saving the company up to \$4419.9 per month. Raw materials savings contributed to 168 tiles per day, which translates to \$2993.76 per month. Lead time reduction from 8467 seconds to 5657 seconds, by 46.8 minutes, contributing upto 12% of production time.

## 6. METHODOLOGY

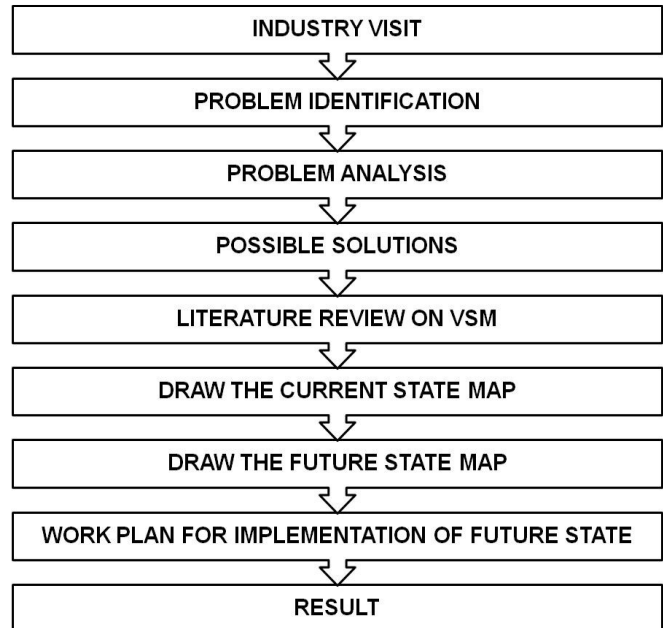


Fig. 1 Methodology

## 7. STUDY OF ALUMINIUM JUNCTION BOX & ITS PROCESSES.

A Junction box is an enclosure housing electrical connections, to protect the connections & provide a safety barrier. Also it is a cabinet for electrical or electronic equipment to mount switches, knobs & displays & to prevent electrical shock to equipment users & protect the contents from the environment, also to be pleasing to the eye. Regulations may dictate the features & performance of enclosures for electrical equipment in hazardous areas, such as petrochemical plants or coal mines. Electronic packaging may place many dem&s on an enclosure for heat dissipation, radio frequency interference & electrostatic discharge protection, as well as functional, esthetic & commercial constraints. Also there are so many application of Junction box like in Lokomotives, Mining, Process control, Automation, Crane hoisting, Solar Panels.etc. Aluminium Junction made up by die casting process. Following are the basis post production processes,

**Linishing** Linishing is a type of finishing technique used to smooth or flatten metal objects.

In Junction Box, Linishing is done with the help of abrasive linishing belt there are different sizes of belts they are use according to the type of finsh required.

**Vibro** This is also finishing process used to deburr, radius, descale, burnish, clean, & brighten the object, The machine has a steel bowl lined with rubber or polyurethane which is filled up with required media (either ceramic, plastic, maize etc. depending upon the finish required) & components.

Eccentric weights are mounted on an extended shaft attached to a heavy duty motor to cause vibrations & create a spiral of the media & the components. Variations in vibration, achieved by varying weights & angles, & suitable combination of media enable machine to be used for different components. In Junction Box Ceramic media is used for finishing.

**Machining** (Drilling & Tapping) **_Drilling** is a cutting process that uses a **drill** bit to cut a hole of circular cross-section in this case of JB drilling done on Lid & Base. After drilling **Tapping** is done on the same hole to do threading inside a hole so that a cap screw can be fit properly at time of assembly.

**Powder Coating** Powder Coating is a type of coating that is applied as a free-flowing, dry powder. In Junction Powder coating first the aluminium pretreatment process is often done as RoHS-compatible chromate conversion coating or Phosphating of Aluminium. The process involves degreasing, rinsing, etching, deoxidation & chromatising or phosphating. This varies based on the composition of the metal to be powder coated & end customer specification. Already pretreated Junction boxes are dry cleaned & powder is spread electrostatically on to them in an enclosed dust free chamber. There are various types of powder like pure epoxy, epoxy polyester, pure polyester. etc. used according to customer requirement also there are different colours requirement from customers like Black, Blue, Grey Junction Boxes. The coated boxes then move to oven for curing at the required temperature as specified by the powder manufacturer or as required for the component to be cured well & to bond with the base metal so as to achieve the desired finish.

In XYZ Company demand of Junction boxes is 15000 no. per month, effective number of working days for all processes are 26 per month, number of shift per day is 11 working hours for all process is 11hrs. Takt time comes out are 68.64secs. Details regarding cycle time, effective cycle time, inventory time, lead time, up-time, no. of operators shown in Appendix-1 for current state map & Appendix-1 for future state map.

## 8. CURRENT STATE MAP- APPENDIX ATTACHED.

Acting upon the gap areas identified by the VSM of the current state, it is seen that except two processes all processes are under the takt time, hence capacity of process is not a constraint for the Lead Time, so following Kaizen projects is identified from the CSM.

### 5.1 KAIZEN-1 Reduce Measurement System Variation between Casting Supplier & XYZ Company.

We have seen in CSM since cycle time of incoming inspection at XYZ is more than the takt time leads to higher lead time. Therefore Casting Incoming inspection at XYZ needs to eliminate. Methodologies used for the same is explain as below,

#### Incoming Rejection Percentage Trend –

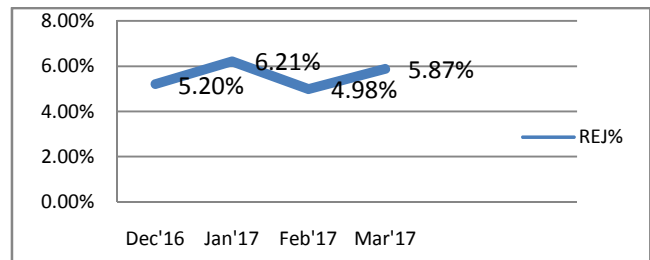


Fig. 2 Incoming Rejection %

Considering last 4 months rejection % found that Avg rejection % is 5.57%. Rejection % is high due to major difference between XYZ Company & Supplier inspection capability. So we have work on measurement system.

#### MSA by Agreement Attribute Analysis.

Since Process Output is attribute parameter, we have selected Agreement Attribute Analysis. Measurement system analysis (MSA) is an experimental & mathematical method of determining how much the variation within the measurement process contributes to overall process variability. Attribute data is based on upon counting how many units fall into discrete distinctions such as: pass/fail or percentage defective. Attribute Agreement Analysis is the Measurement System Analysis method used to analyze measurement systems for attribute data.

#### MSA Study Design :

Inspection method : Visual.

- No. Of operators: 3 from supplier, 3 from XYZ.
- No of parts : 50
- No of trials : 3

We have started with the evaluation of rejection trend of incoming inspection. Considering last 4 months data of incoming castings rejection, we have seen that average monthly rejection is around 5.57%. This is due to major difference between XYZ Company & Supplier inspection capabilities. Since Process Output is attribute parameter, we have selected MSA Agreement Attribute Analysis, for the analysis we have taken 50 parts & 3 inspectors from XYZ Company as well from the Casting supplier & taken three trials of inspection & compared with reference of quality. From the analysis it is found that at supplier end Kappa coefficient is less 0.75 which means that measurement system at supplier end is not in line with requirement of

quality standard since as per thumb rule for excellent agreement kappa value  $> 0.75$ .

Hence to improve the performance of measurement system Training is conducted at supplier end & again at XYZ also, after training again MSA done at both level & result observed from MSA is that measurement system kappa coefficient is greater than 0.75. Effectiveness of MSA monitor for the next lot of inspection & result observed was there is reduction in casting rejection percentage from 5.31% to 2.01%.

#### Effectiveness monitoring after reduce variation of Measurement System

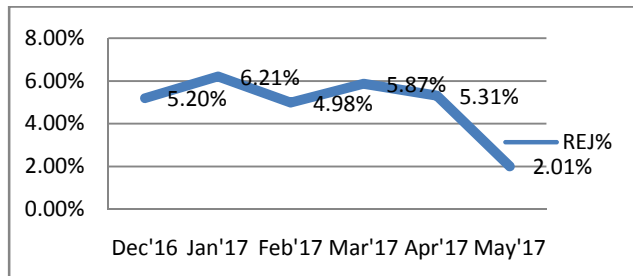


Fig. 3 Incoming Casting Rejection %

#### 5.2 KAIZEN 2- Eliminate Touch up rework for Powder Coating

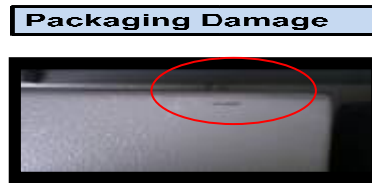


Fig. 5. Defect Description

#### Tool description – Defect Concentration diagram

We have studied different Quality tools/techniques from the study it is found that individual tools have their importance to identify different types of causes.

What is it used for: To show the location of errors or defects

#### Concentration diagram – for Touch up location

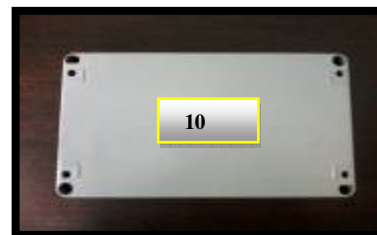
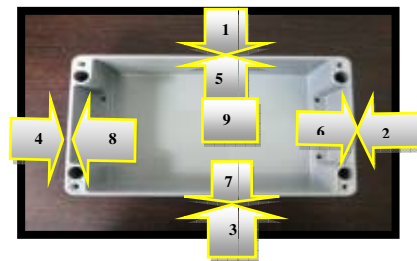


Fig. 6 Concentration diagram

#### Touch up rejection trend :-

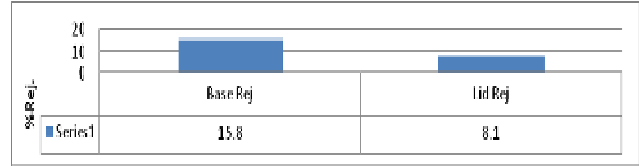


Fig. 4 Touch up rejection trend

We have studied the rejection trend as above for two months data separately for the lid & base it is found that average rejection for the base is 15.8% & Lid is 8.1%, based on the visual inspection it is analyze that, type of damages found was packing damages & h&ling damages.

Among the various quality tools we have studied Defect Concentration diagram is used show the location of errors or defects. When either capturing or displaying defects data that can be segregated by location.

#### Defect Description

Based on visual inspection it is analyze that, type of damages found was packing damages & h&ling damages as shown in fig. below,

Why use it: To determine where the faults are occurring on the production part.

When to use it: For either capturing or displaying defects data that can be segregated by location.

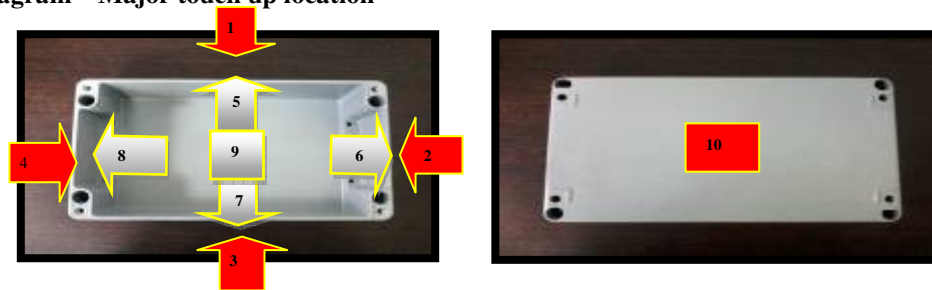
First we have started with identification possible zone. After that Concentration Check List for Base & Lid is done, where causes for defect are segregated zone wise.

**TABLE 1: Concentration diagram – Zone wise trend**

JB Zone	Base	Rej %	JB Zone	Lid	Rej %
Zone 3	57	21	Zone 3	27	26
Zone 4	52	19	Zone 2	21	20
Zone 2	45	17	Zone 4	16	16
Zone 1	40	15	Zone 1	15	15
Zone 10	34	13	Zone 10	6	6
Zone 9	16	6	Zone 6	4	4
Zone 6	12	4	Zone 8	4	4
Zone 7	7	3	Zone 9	4	4
Zone 8	5	2	Zone 5	3	3
Zone 5	3	1	Zone 7	3	3

After analysis we have found 84% damages on outside area ie. max on zone 1, 2, 3, 4 & 10. Again the concentration diagram is drawn with the major contributor of the damaged problem. as bellow,

**Concentration diagram – Major touch up location**

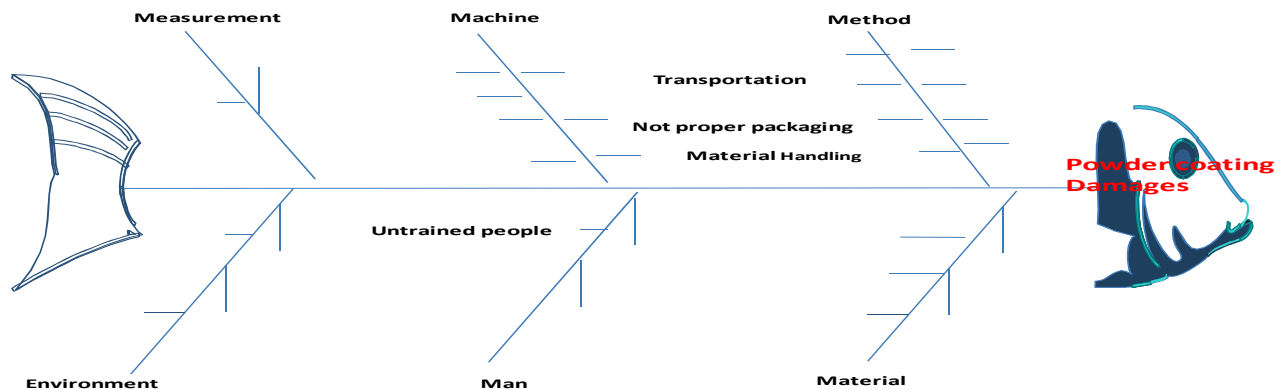


**Fig. 7 CD Major touch up location**

Conclusion: Analysis denotes that zones indicated in the red box are the major contributor of the damaged problem. So now we have to find the causes for damages.

**Cause & Effect diagram (CE) Diagram: Powder coating touch-up.**

A cause & effect diagram, often called a “fishbone” diagram, can help in brainstorming to identify possible causes of a problem & in sorting ideas into useful categories. A fishbone diagram is a visual way to look at cause & effect.



**Fig. 8. CE Diagram for PC**

**Training program for packaging improvement in XYZ & Coating supplier**



**Fig. 9. Training at XYZ & PC Supplier**

**Before Improvement Photograph**

Previously we were sending the powder Coated material in bin & corrugated boxes.



**Fig.10 Before Improvement**

**After Improvement Photograph**

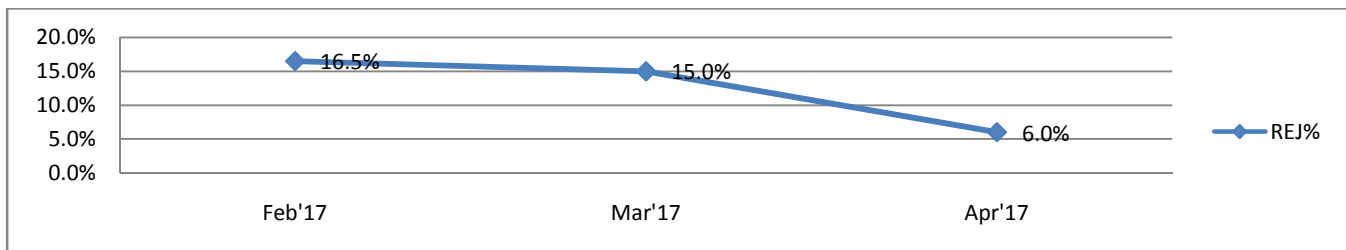
We are started the powder coated parts Packaging with polybag to avoid the damages.



**Fig.11 After Improvement**

**Rejection Improvement monitoring**

It is observed that after analysis rejection trend reduce from 15% to 6%.



**Fig. 12. After analysis rejection trend**

**9. FUTURE STATE VALUE STREAM MAP  
APPENDIX ATTACHED**

**10. CONCLUSION**

**Research conclusion**

Lean Manufacturing is applicable for all the type of the organization irrespective of their size, lot of work has been carried out in manufacturing sector that to in different functional areas, the level of implementation varies across the sectors & their size.

Conclusion of this study reveals that the successful Lean Manufacturing System implementation needs integration & simultaneous implementation of Lean elements along with proper sequence. Thus the proposed implementation structure reduces the implementation duration & reduces manufacturing system divergence. As a result it is proposed that the Lean Manufacturing System can be sustained in competitive business environment.

**Case study conclusion**

Conclusion of the study is that after detailed analysis, VSM & Kaizen technique is successfully implemented in post production processes of Junction Box manufacturing with the reduction in lead time from 30.33 days to 21.14days.

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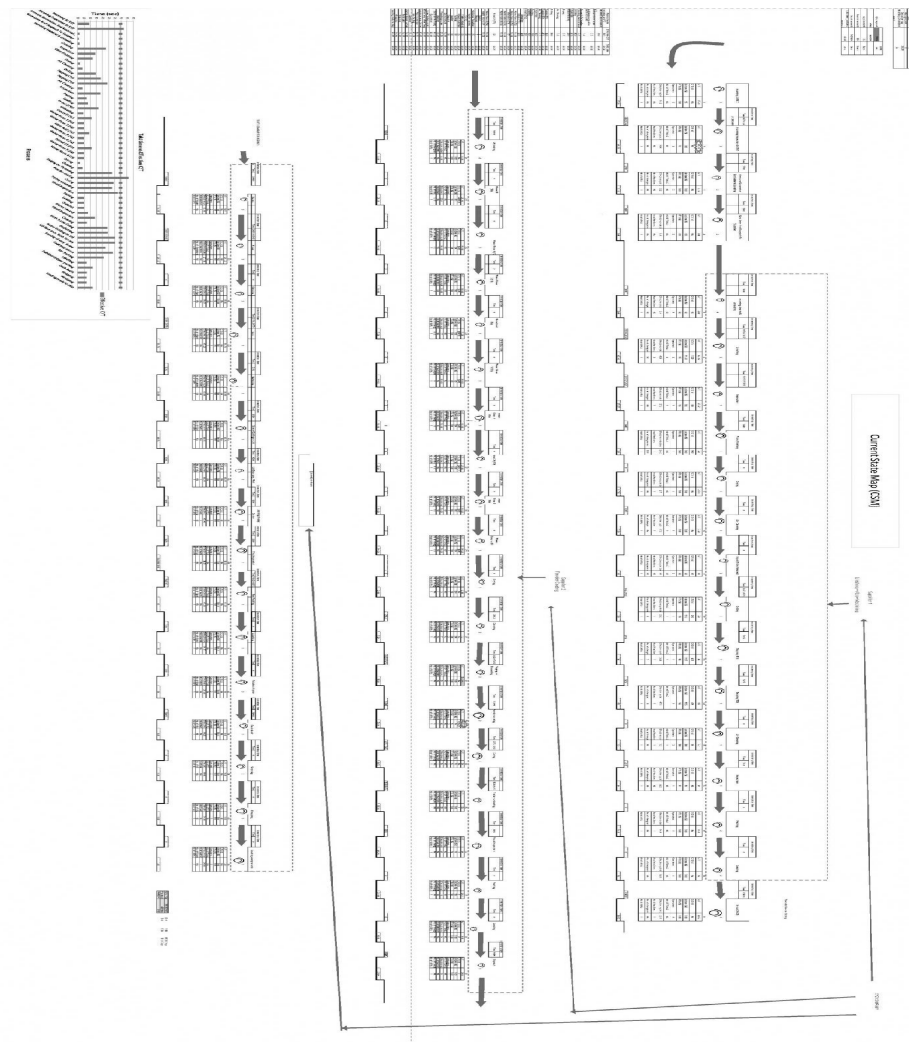
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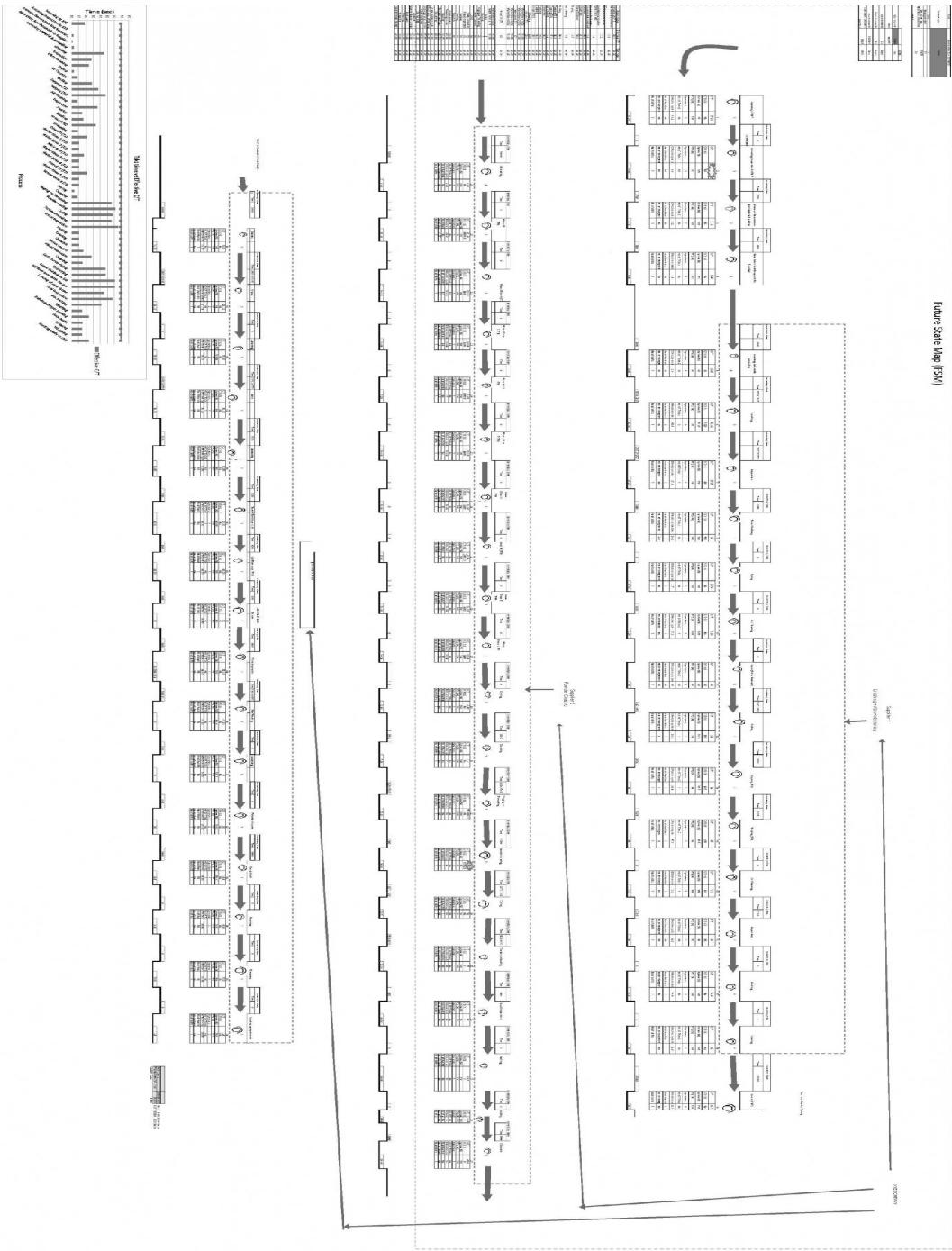
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#### APPENDIX ATTACHED:





# 5-S Implementation to Reduce the Lead Time via Applying Time and Motion Technique for Identification of Wastes: A Case Study of Small Scale Pipe Industry

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**Abstract:** A Company is like a living organism. A worldwide increase in demand for products has caused sales to increase tremendously in the peak season. The increased workload at the plant has resulted in longer lead-times. The manufacturer is inefficient because it has poor product flow due to operations being departmentalized. The increase in lead-times could cause a loss in the market share to its competitors. The manufacturer must reduce its lead-times in order to remain competitive and continue its growth by providing quality products in a timely manner. The objective of this paper is to develop a plan for eliminating the wastes and consequently reducing lead-times by implementing 5-S in HDPE section of pipe industry. A time and motion study has been done in point areas that have potential for improvement. 5-S will then be implemented to reduce lead-times and increase throughput.

**Keywords:** 5-S, HDPE.

## 1. INTRODUCTION

Now days when there is cut and throat competition in the market, it is very difficult for an organization to sustain. Customer requirements changes rapidly, fluctuations in the requirements of the product in market come out to be challenging task for the manufacturer point of view. Therefore, the manufacturer has to respond quickly and accurately as per the market demand to fulfil the customer need. So the organization should focus on all issues during the product development activity, starting from identification of customer needs to last activity that is delivery of the product to the end user. This objective can only be completed when every employee should do their own work with 100 % efficiency. Also the workers should complete all the process in such a manner that will be effective. Various techniques have been applied up to till date to achieve this objective. Some of them are like 5S, Kanban, Just in Time concept that will not increase the productivity but also improve the customer relationship. This paper shows the application of 5S concept which is originally a Japanese concept but now a day's applied worldwide all the industry.

### 5-S Concept

The 5-S is a philosophy, which focuses on effective workplace organization and standardized work procedures.

It is based on five Japanese words that begin with S.

The 5-S philosophy originated in the post World War II era (probably in the mid 1950s) in Japan. At that time, Japanese manufacturing companies were forced to produce with a very few resources, so they developed a shop floor method to make every scrap count while wasting nothing. Originally there were only four activities in the Japanese system, each beginning with the letter S. They were -

**SEIRI** - Sorting

**SEITON** - Setting in order, straightening, simplifying

**SEISO** - Sweeping, Shining, Systematic Cleaning

**SEIKETSU** - Standardizing

Later, a fifth activity was added, called SHITSUKE (sustaining), which completed the five S elements known as 5-S. Today, the 5-S system retains its fundamental power to change the workplace & involve everyone in the improvement process. It is a system, to reduce waste and optimize productivity through maintaining an orderly Workplace to achieve more consistent operational results. It may be applied to any workplace for a short period of time due to its simple nature.

The brief description of 5-S is as follows:

**TABLE 1.1: 5-S Meaning & Objective**

The 'S'	5-S Element	What is Involved?	Objective
1-S	SEIRI	Separate necessary items from unnecessary	Proper utilization of space



The 'S'	5-S Element	What is Involved?	Objective
		items.	
2-S	SEITON	Proper arrangement of each and everything which is required for production .	Less time required to find the required items.
3-S	SEISO	All the equipments and tools which can be used should be clean and dust free so that it will work efficiently.	To increase the efficiency of the tools and equipments.
4-S	SEIKETSU	How to complete the wok, the instruction and method of doing work should be easy and simple.	To reduce the Non value added activity so productivity will be improved automatically.
5-S	SHITSUKE	Staff and people should be discipline and honest to perform their work and duties.	Try to maintain the good and healthy couture of doing all necessary thing.

## 2. LITERATURE REVIEW

### 2.1: Wastes

Wastes mean everything which is not required by the end user. If something made by manufacturer which is exceeds the requirements of the customer is comes under the category of wastes because it increases the problem of inventory .Inventory may be in any form may in the form of raw material or complete products. It required human being, time and money which will increases the cost of the company. Bottleneck s on the line increases the waiting time of the next process. So it is also a wastes. Some time a machines remains idle until a product is processes on the preceding line and also some time product has to be wait for processing therefore waiting is also a wastes which interrupt the smooth flow of the processing of the product. Movement of the material is also a type of wastes which required the human effort, time and energy. Because for material handling, sometimes necessary and sometime it is unnecessary. Necessary because material is required to be processed on different line to complete all the features of finished goods. But many times it has been observed that unnecessary it is moved then it should be avoided. Sometime because of wrong processing of material, manufacturing defects, design mistakes and also understanding of wrong need of the customer will create a huge level of wastes. Mistakes can be done at any level so accuracy counts here because it saves a lot of time. Maintenance may be in te form of preventive or breakdown will not produce anything which will generate the value to the customer so this is also a type of wastes.

All the above type of wastes comes under the category of Non –Value Added activity which only consumes resources and giving any worth to the value creation in product. The activity which is actually required to make product are called as the Value-added activity. These are the only activity for which the customer is only willing to pay. Efforts have been made in different sector, worldwide by

researcher previously to reduce the different types of wastes but here the key factor is that everybody should be determinant to do their best. Support at all levels by everybody, Proper coordination is the key of success.

## 3. CASE STUDY

### 3.1 Brief Introduction to the Various Lines:

Company ABC is a pipe industry in which various products are processed on different line as per the requirement of the end user. Various sections in the plant are as follows:

1. RPVC Pipe section
2. RPVC Suction Line
3. HDPE LINE
4. Molding Plant
5. Belling Plant
6. Secondary processes plant

**HDPE Line:** High Density Poly Ethylene pipes are 20 feet long. These pipes are used for agriculture purpose and some type used in industry of draining of Industrial wastes.

## 4. OBSERVATION TABLE & DATA COLLECTION

Though there were lot of products are manufactured on different section but focus has been shifted to only HDPE section. Same study can applied to other section of the plant.

### 4.1. Material Type Flow Process Chart

These shows the events occur to the materials in the plant. The various data are recorded in the plants which are as follows.

S. No.	STEPS/ELEMENT WISE	TIME (SEC)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY
1	The bags of RPVC are arrived near the" HDPE GODOWN".	1074	2					
2	The Two persons start unloading.	117	2					
3	The other labors put the bags in the godown.	1584	18					
4	The labour puts RPVC to Issued Material Section.	118						
5	The bags of raw material put near the container.	138	2					
6	The waste material is put near the container.	502	2					
7	The bags of raw material dropped in the container.	598	1*					
8	The waste material is dropped in the container.	275						
9	The granuals & waste material is mixed in the container.	183	1*					
10	The final mixture is prepared.	428	1*					
11	The final mixture is filled in the bags.	48						
12	The bags of final mixture are put near the mixture hopper.	232						
13	The final mixture is dropped in the hopper.	12	1					
14	The desired material is prepared in the mixer machine.	429	NILL					
15	The desired material is sucked to the Extrusion process.	15						
16	The pipe is prepared.	2702	1					
21	The pipe is dropped automatically in the first trolley.		1					
22	The pipe is waited for second trolley.	809						
23	The pipe is trimmed and cleaned.	21	2					
24	The trimmed pipe is put in second trolley.	24	2					
25	The pipes are laid in the second trolley.	1208	NILL					
26	The pipe is marked manually.	247	1					
27	The marked pipes are laid in the second trolley.	1124	NILL					
28	The second trolley is moved outside the RPVC section manually.	244	4					
29	The pipes in the trolley are tightened by the rope.	112	2					
30	The trolley is moved for secondary process/belling plant.	258	1					
	TOTAL	12502	42					
	OPERATORS	3989	5					
	VALUE ADDING %	31.9	11.9					

From this table it is concluded that only 31.9% of time is Value added and rest of the time is in the form wastes (i.e. transport t, Storage and delay).

#### 4.2 Standard time SHEETS (HDPE Pipe):

<b>St. Time= Basic time + Allowance</b>
-----------------------------------------

Standard time SHEETS (HDPE Pipe)(All the time is in Seconds)						
S.NO.	STEPS/ELEMENT WISE	O.T	RATING	B.T.	ALWN	ST
1	The labour puts raw material in the Issued Material Section.	122.71	0.8	98.17	0.16	98.33
2	The bags of raw material are, put near the container.	141.28	0.8	113	0.16	113.2
3	The waste material is put near the container.	504.14	0.8	403.3	0.16	403.5
4	The bags of raw material are dropped in the container.	602.71	1	602.7	0.16	602.9
5	The waste material is dropped in the container.	262.14	1	262.1	0.14	262.3
6	The granuals & waste material is mixed in the container.	184.85	1	184.9	0.14	185
7	The final mixture is prepared.	431.14	0.9	388	0.14	388.2
8	The final mixture is filled in the bags.	51.85	0.9	46.67	0.17	46.84
9	The bags of final mixture are put near the mixture hopper.	233.85	0.9	210.5	0.17	210.6
10	The final mixture is dropped in the hopper.	14.85	0.9	13.37	0.17	13.54
11	The desired material is prepared in the mixer machine.	431.14	0.9	388	0.15	388.2
12	The desired material is sucked to the Extrusion.	51.85	0.9	46.67	0.17	46.84
13	The pipe is prepared.	2705.14	1.2	3246	0.15	3246
14	The pipe is dropped automatically in the first trolley.	11.42	0.8	18.06	0.14	18.21
15	The pipe is waited for second trolley.	811.57	1	811.6	0.17	811.7
16	The pipe is trimmed and cleaned.	24.28	0.6	14.57	0.17	14.74
17	The trimmed pipe is put in second trolley.	25	0.8	20	0.13	20.13
18	The pipes are laid in the second trolley.	1210.71	0.8	968.6	0.14	968.7
19	The pipe is marked manually.	247.71	1	247.7	0.15	247.9
20	The marked pipes are laid in the second trolley.	1125.71	1	1126	0.14	1126
21	The second trolley is moved outside the RPVC.	245.42	1	245.4	0.13	245.6
22	The pipes in the trolley are tightened by the rope.	114.42	1	114.4	0.13	114.6
23	The trolley is moved for secondary process/belling plant.	254.57	1	254.6	0.13	254.7

#### 5. 5-S IMPLEMENTATION IN THE HDPE:

##### Seiri:

1. PVC resin.
2. Small bags for feeding the resin.
3. Extruder
4. Recoiler
5. Stool for operator
6. Weighing machine for check the finished pipe weight
7. Haul off
8. Bath tube
9. Cutter
10. Trolley & rope for tightening pipes in the plant
11. Weighing machine for check the finished pipe weight

##### Seiton

1. All the dies are arranged properly for easy retrieval.
2. Different types of chemicals arranged in the rows.
3. Required RPVC Resin is also put in bags in rows.
4. Proper space for placing the bags near the hopper.
5. Proper place for packaging material etc.
6. Proper place for subassembly parts.

##### Seiso Sweeping, Shining, systematic cleaning

1. In the mixing room, the PVC resin, chemical mixture are spread on the floor area, this may cause the slippery action on the worker & cause the unwanted causality, so cleaning of the floor is very much essential in mixing room.

2. Extruder is cleaned at regular interval because grease, oil and wastes material rushes regularly.
3. Some wastess / scrap near the die are spread, this is removed regularly.
4. Dust and dirt is removed at regular interval.

#### Seiketsu: (Standardizing)

In first three steps a lot of effort and support is required from all employees of the organization. So 4th S relates to make the benchmark so that everyone feel comfortable to implement the above 3S. The Practice should be make to follow all the efforts up to a standard value

#### Shitsuke: (Sustaining)

To implement this step biggest problem is that it is very difficult to change the habits of human being. Operators, who are involved in manufacturing generally do not follow the above concept for a long time. It is not a onetime affair .people should be honest to follow the same instruction and do not deviate from the basics.

## 6. RESULTS AND INTERPRETATION

### From – To Chart:

From -To chart is the one of the best chart to identify the motion of material in the plant. The From-To Chart is a square matrix with the number of rows (columns) equal to the number of departments/workstations in the problem.

**TABLE 6.1: From – To Chart of HDPE Line**

From To	A	B	C	D	E	F	G
A		396m					396 m
B			96.67 m				96.67 m
C				49.22 m		86.12 m	135.34 m
D					30 m		30 m
E						63 m	63 m
F	232 m			74 m			306 m
G	232 m	39 m	96.67 m	123.22 m	30 m	149.12 m	1027.01 m

Here symbol A-Gate, B-Store, C- HDPE Plant, D- Butt Welding Section, E- Testing Section, F-Yard, G-Total Distance

In this analysis we will neglect the material movement within the department. HDPE pipes moves 1027m, within the plant. To analyze and identify such a large amount of lead and the main causes behind the large amount of non value added time the Root Cause Analysis is done. It shows that transportation and delay is responsible this huge amount of non value added time.

In the **HDPE plant**, The production lead time = 444816 secs.

After **standardized** the work, the lead = 357618 secs.

So reduction in the lead time =  $(444816 - 357618)/444816 = 19.60 \%$

After the **5-S Implementation** the lead time = 262331 secs

So **reduction in the lead time** =  $(444816 - 262331)/444816 = 41.02 \%$

In HDPE product the lead time is reduced that 41% after implementing the 5-S.Wastes is mainly in the form of Overproduction, Transportation and Delay.

## 7. CONCLUSION AND FUTURE SCOPE

It has been concluded that the main reason for waste formation in the company is the improper coordination among the employees, inadequate planning and demotivation of the employees which results the wastes in the form of unnecessary transportation, Delay and Storage may be permanent storage or temporary. Unnecessary transportation can be improved by managing the workplace that means by correcting the plant layout, Delay can be avoided up to a certain limit by applying the concept of Just in time and kanban and Delay and storage can be reduced by eliminating the bottlenecks of the line by proper sequencing of the machines.

This paper represents the use of 5 S concepts at only one line and result shows the magic of this concept. Similar it can be applied in all the line of the plant so total lead time of the product will be reduced significantly.5S concept in the plant generally implemented along with other concepts like JIT and Kaizen etc. As we reduce the lead time, We will automatically increased the customer satisfaction the is the need of today's industry.

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# Process Improvement through Lean: A Case Study

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**Abstract:** Lean Manufacturing (LM) is a term used to describe manufacturing practices that eliminate the waste (MUDA) during any part of the manufacturing process. It emphasizes the use of processes that do not delay the delivery of product, employee involvement, or synchronized way of all production and managing shop floor operation. LM stresses on reducing waste, rationalizing materials, and standardize components, to help make products more efficient to build. This paper presents the details of a case study. It highlights the road map of the company for achieving performance improvement through LM implementation and its impact on organizational performance. It also points out strengths and weaknesses of LM implementation practices and overall performance using developed research instrument. The case study helps in evaluating the company's LM implementation and overall growth of SMEs. To do so, research instrument was administered amongst forty four employees in the three SMEs respectively and their responses were analyzed. Using the data obtained from a survey of industries in India, the identified factors were subjected to appropriate statistical tests to establish reliable and valid model. Statistical computing package SPSS 20.0 for Windows was used for reliability and validity analysis. The validated instrument of LM factors developed here may be used by manufacturing organizations to priorities their management efforts to assess and implement LM. The validated results are in Indian context; however, the instrument developed can be used in global context.

**Keywords:** Lean Manufacturing, Critical Success Factors, Reliability Analysis, Factor Analysis

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## 1. INTRODUCTION

Henry Ford first developed a concept of manufacturing assembly line in constant motion - the first method for mass production. The model Henry Ford performance for a worker in the most simple and repetitive tasks have been replaced by job rotation and teamwork, mainly to improve employee morale, but also provide significant benefits in terms of higher quality and suggestions of employees to improve the process. This model is changing the way managers see production, the emphasis is on the specialization of information work performed by unskilled labor. The spread of mass lower cost per unit, work standardization, volume products supported by the school and the founder of scientific management Frederick Taylor. Until TaiichiOhno Toyota Group in Japan pointed out some flaws in the model, the effect of the model is not challenged by managers. Mass production requires large amount of capital and space, poor quality of products, high inventory levels of materials needed in product standardization and related organizations are resistant to change and very inflexible demand customers. Lean manufacturing practice or production system Toyota initiated by the Japanese automaker under the strong leadership of its quality engineer TaiichiOhno, 1988, later it was popular as a parent to lean manufacturing, and the new framework is implemented in manufacturing at the time of the financing deficit and economic crisis after World War II in Japan. Lean is to identify the Manufacturing SMEs are active in Gujarat provide significant revenue to the government of

Gujarat and the country. Lean manufacturing is a way to achieve excellence in manufacturing. Lean manufacturing is a philosophy, a production strategy and a set of techniques to meet customer needs with the minimum of all resources. Lean manufacturing tools eliminate waste in the system, thereby reducing the manufacturing cost. Lean manufacturing results in reducing manufacturing time manufacturing, WIP reduction, better space utilization, improved quality, increased customer satisfaction and ultimately increase productivity. Driver cost of manufacturing down and allows an organization to be competitive in the market and become more profitable. Lean manufacturing practices have much attention as a practical world-class manufacturing due to the effective and continuous improvements in everyday work value (all you can produce money) and incorporate techniques to minimize waste and rework with effective machines, and active participation of employees in the commitment line. From the origins of the idea Lean Toyota Corporation, these principles have moved to other Japanese car manufacturing and then to the US auto companies such as benchmarking and improvement techniques.

### 1.1 Small and Medium Scale Enterprises in Gujarat

The state of Gujarat is one of the highly industrialized states in India with its reputation as a very investor-friendly state. The state has a proven track record of attracting large amounts of investment will be most favored investment destination in India (Socio-Economic Review, Gujarat,

2011-12) history. In the current scenario of privatization and globalization, small scale industries facing tough competition and thus the survival and growth of these industries will be a tough challenge. Some industries consistently get growth under competitive conditions, while others do not. As a result, new opportunities and threats appeared on all types of industries in India (MSME Annual Report 2010-11). SMEs play an important role in the national economy, especially in the economy such as ours, which is growing.

According to the Economic Survey 2012-2013, Gujarat ranks second after Bihar in the list of fastest-growing state during the past seven years. Between 2005-06 and 2011-12, Gujarat registered an increase in gross domestic product (GSDP) of 9.98%, while Bihar recorded the highest growth rate of 10.17%. The growth of industries in Gujarat is very impressive and growing every year, which is also shown in the chart below (Socio-Economic Review, Gujarat, 2011-12)

## 2. REVIEW OF LITERATURE

Critical success factors (CSF's) are the vital input factors that will drive a good LM system. Different authors have attempted to investigate the CSFs in LM with differing purposes and objectives. Critical factors should be interpreted as those circumstances or practices which already exist, or those that need to be developed in ensuring the success of LM implementation. Performance measures are deliverables or output of a LM system. Improving organizational performance is a goal of every organization. Organizational performance is the final result of running a business. It can reveal the effects of doing business, show the competitive capability of the firm in the market place and its financial status. Organizational performance is a good indicator to test the effects of improvement practices and of companies' efforts in pursuing performance measures. An objective of this study is to evaluate the factors which have positive impact on the organizational performance indicators in Indian manufacturing companies. The requirements of LM critical success factors and performance measures proposed by various authors are briefly described below.

In research (Hines, 2004) Holwe & Rich raises awareness of the vision of managers. The main aim is to develop into lean philosophy and develop an understanding level of the hypothetical foundations of organizational culture. In "The machine that changed the world", Womack and Jones claim that the implementation of an approach "will change almost everything in all industries - options for consumers, the nature of work and the wealth industry by combining the benefits of art and mass production." Lean tactic contains of several methods, its purpose is to improve the quality, efficiency and responsiveness to customers. Lean as a concept has evolved over time. The researchers based their

research effort on the structural framework proposed by McGill and Slocum (1993) for the association between values and achieve balance cost and cost value.

Todd (2000) defines Lean Production "initiative, which aims to reduce waste of human effort, inventory, time to market and production space to respond to customer demand and produce the highest quality products in the world," the most well-organized and inexpensive way.

The curiosity in constant development led to the concept of a learning of the organization. Opens new opportunities for improvement and achieve long-term sustainability. In direction to demonstration the development of the idea of Lean from the original application of the first major use as a technique to target today's culture to improve organizational learning, the four steps in the development of the Strategy reading are discussed in detail:

McGrill and Slocum (1993) classified four types of organizational learning as mentioned in (Hines, Holwe & Rich 2004). The steps in the development of lean philosophy is related to the different stages in the growth of organizational closure. Fiol and Lyles, 1985, in accordance (Hines, Holwe & Rich 2004) defines organizational learning as "the process of improving actions through better knowledge and understanding."

Rockart (1979) has defined the CFS as a "limited number of areas that will result if successful, will ensure competitive success of the organization." Critical success factors are crucial for the success of the programs and objectives associated with these factors achieved extensive, application programs available.

The term ERROR (Rockart, 1979). When asked to Boynton and Zmud (1984) CSF years, "so get things to go well to ensure success." CSF measured and processes that are controlled by management to achieve the objectives of the organization (Brotherton and Shaw, 1996) diet. All improvement initiatives involve higher costs, investments (Ranjan and Bhatnagar, 2008) and high risk (Umble et al., 2003) for an organization. Therefore it is important to identify factors that diets that determine the success and avoid the risk of failure. If not selected in these CSF, not only can be a significant difference in success, men Aventure losses in labor, time and money (Coronado and Antony, 2002). The critical success factors are important elements that must be resolved by cable or responsible for that "things should go quickly, " of a project or activity to achieve the objectives for the management and growth of the project. I agree with. I implement Six Sigma projects, CSF represents the most important ingredients, but whose application has little chance of success. A number of researchers have examined the role of CSFs in lean application.

### 3. LM FRAMEWORK

Depending upon the critical success factors and performance measure a validated instrument of LM factors is developed .Based on the information provided by the respondent and the analysis of survey data about LM implementation for manufacturing companies in India, a

LM frame work is developed. Statistical methods such as descriptive statistics, factor analysis, correlation analysis, regression analysis and hypotheses testing were used in the analysis. Table1 shows the strong and weak relationship between the various LM implementation factors and the Performance measures.

**TABLE 1: Relationship Matrix for LM operational Model**

Sr.No	Organizational Performance Measures	Relationship with Lean Manufacturing Critical Success Factors-CSFs	
		Strong	Weak
1	Quality	1. Customer Focus     2. Human resource management     3. Performance management     4. Strategy     5. Top Management	6. Employee Management     7. Financial capabilities     8. Organization Culture     9. Process management     10. Skill Development     11. Supplier Network
2	Cost	1. Customer Focus     2. Employee Management     3. Financial capabilities     4. Human resource management     5. Skill Development     6. Supplier Network	7. Process management     8. Performance management     9. Strategy     10. Top Management     11. Organization Culture
3	Delivery	1. Financial capabilities     2. Performance management     3. Skill Development     4. Supplier Network     5. Customer Focus     6. Process management	7. Top Management     8. Strategy     9. Human resource management     10. Employee Management     11. Organization Culture
4	Flexibility	1. Skill Development     2. Supplier Network     3. Customer Focus     4. Strategy     5. Human resource management     6. Process management	7. Top Management     8. Organization Culture     9. Financial capabilities     10. Performance management     11. Employee Management
5	Customer Satisfaction	1. Top Management     2. Organization Culture     3. Financial capabilities     4. Performance management     5. Employee Management     6. Process management	7. Supplier Network     8. Customer Focus     9. Strategy     10. Human resource management     11. Skill Development
6	Financial Performance	1. Top Management     2. Organization Culture     3. Strategy     4. Human resource	6. Financial capabilities     7. Performance management     8. Employee Management     9. Skill Development



		management 5. Process management	10. Supplier Network 11. Customer Focus
7	Productivity	1. Top Management 2. Organization Culture 3. Financial capabilities 4. Performance management 5. Human resource management 6. Process management	7. Employee Management 8. Skill Development 9. Supplier Network 10. Customer Focus 11. Strategy

#### 4. CASE STUDY

##### 4.1. Objective of Case Study

To verify whether the relationship established is valid through the responses from the industries. The major aim of the case study is to provide a practical example of performance improvement of the Gujarat/Indian manufacturing company that has implemented LM initiative. One of the objectives of case study was to assess the LM implementation practices and performance improvement of the organization. The study was conducted in company that has already implemented this initiative. The case study helps in evaluating the company's LM implementation and overall business performance.

##### 4.2. Brief about the Organization

Company ABC is a Manufacturing and Engineering service provider, utilizing Precision Machinery & Equipment for manufacturing and Inspection. It is located in the State of Gujarat, Chhatral GIDC. Possessing over 15 years of experience in Manufacturing, Production Processes, Design, Quality management. It is equipped with latest technological precision machining machinery and state of art inspection facilities. It offers complete single source reliability and convenience precision machining services in the field of HVAC, Aerospace, Automotive, Medical Devices, Fasteners, and Fittings. It has established System to meet requirements of ISO 9001 and AS 9100 and has extensive experience in all aspects of Design, Development & Supply Chain Management. Their ability to operate with a low overhead cost coupled with Lean Manufacturing practices allows offering competitive pricing while maintaining a high level of quality.

##### 4.3 Key processing facilities:

- CNC/VMC Machine
  - VMC (Hass Make) VF 2 FYT Model 914 X 457 mm Thru-Coolant
- Hot Forging Facility

- 35 KVAMetal Gathering Mc, Upsetting Header, Forging Press150T

- SPM/Automates
  - Single Spindle Automatic Traub A 32 & A 25 MM, Capstone TraubA 32, Roll Thread Machine A 24, Threading SPM 1.00"
- Welding Equipment
  - MIG Welding 400 AMP
- Tool Room Machinery &Equipment
  - HACKSAW Machine 8", Lathe Machine, Drill Machines (upto 24 mm), Surface Grinding Machine

##### 4.4 Processing Options:

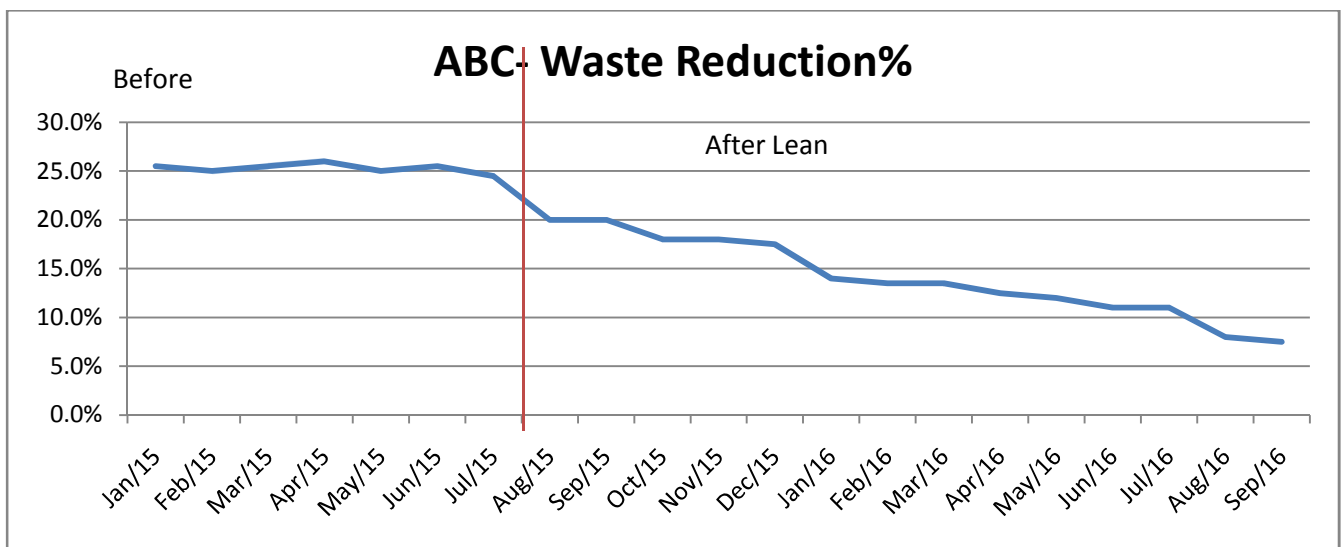
- VMC & CNC Turning Precision Components
- Hot Forged Brass & MS Components
- Conventional Turning Components
- MIG Welded Fabrication Component
- Insert able Molded Components (Rubber & Plastic)
- Post Treatment: ZINC Plating, Hard Anodizing, Yellow Passivation, Blackodizing, Ni - Cr Plating

#### 5. PERFORMANCE IMPROVEMENT PROGRAMS PURSUED BY THE COMPANY (LM IN COMPANY)

The Company has always striven to be responsible and sensitive to inventory wastage and product delivery matters. This is ensured by Planning, Implementing and monitoring all possible Lean drives and human resources, often far beyond what is mandated by government and other institutional policies. The Company is committed to complying in full measure with all regulations relating to waste elimination around its operations. By constantly upgrading technologies and by applying the best of Lean processes and practices, the Company endeavors to provide fast delivery to the customer as the priority they deserve.

**TABLE2: Data Collection for ABC organization before Lean Implementation**

SR NO	Performance Measures	Company	Before Implementation					
			Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15
1	In process stage Rejection	ABC	25.5%	25.0%	25.5%	26.0%	25.0%	25.5%
2	Final rejection stage	ABC	8.0%	8.0%	7.5%	8.0%	7.8%	8.0%
3	Return goods	ABC	10.0%	10.5%	10.0%	10.5%	10.0%	10.5%
4	Cost of Quality / sales	ABC	44.00%	44.00%	44.00%	45.00%	42.30%	44.50%



**Fig. 1. Waste Reduction**

As shown in figure 1 the ABC organization has a significant rejection in process stage of manufacturing in the month of January to June, which was actually before lean tools implementation and from the month of July 2015 Company started the implementation and achieved the reduction in rejection/waste elimination by 71 % as shown in the figure.

## 6. EVALUATION OF LM IMPLEMENTATION AND ORGANIZATIONAL PERFORMANCE

In order to evaluate the company's LM implementation practices and organizational performance, the developed research instrument was used. Based on the evaluation, the current situations of the company's LM implementation and overall performance were obtained. Subsequent sections present the evaluation results, which were translated into marks according to the scoring methods. It also highlights the extent of relationship (little, moderate, large) between various LM implementation practices and overall performance.

## 7. CONCLUSION

The case study highlights the weak areas which can be used as possibilities for the company to improve its LM implementation and overall business performance. However, it should be noted that even its strong areas are not at all perfect as indicated by marks scored by respective items; they still have room for improvement. Strong and average areas are just a relative sense compared with the company's weak areas, though weak areas should receive more attention. The weak areas of the company's LM implementation can be used by the company to formulate improvement plans. The various performance indicators show remarkable improvement over the years. The company has achieved both tangible and intangible benefits by practicing this approach. The case study shows that LM approach can be used to Benchmark Company's continuous improvement, self-assess their quality improvement efforts and measure their progress over time. Through this, company can quickly identify which areas urgently need improvement. Thus, resources can be allocated more

wisely. The results obtained from the implementation of LM initiative were encouraging for the organizations, and also substantiated the model. The organizations also benefited through the improvement in various areas and because of LM implementation the organizations have continuously improved their performances. In the process the organizations received appreciations from their customers and also gained significant benefits through LM implementation. The concerns also certified that 'The LM Implementation (Performance) Model' developed by the researcher through his research study served as a useful guidance in successfully implementing LM practices in their organizations and in achieving better organizational performance.

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# Productivity Study of Engine Assembly Line using MOST: A Case Study

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**Abstract:** It is evident that to sustain in this competitive industrial environment, a company needs to reduce or eliminate the idle and/or downtime, improve the working methods, standardize the time as well as enhance the overall capacity planning and in this respect, the MOST can play a vital role. This study highlights a MOST methodology developed for minimization of non-productive activities or non-value added activities (NVA), minimization of fatigue and revealed the excessive movements of operators. This case study is done in the heavy duty engine assembly line of Vehicle Manufacturing Industry. This study shows significant benefit associated with the implementation of MOST which help in effective utilization of available resources as work content of assembly line as much non-valuable activity which can be eliminated by new fixture, layout & implementing new method of work. It is one in all the vital work measuring technique which gives an alternative to the Time Study method and it is conceivable to accomplish a significant reduction in production time which helps in improvement in productivity.

**Keywords:** MOST (Maynard Operation Sequence Technique), Productivity, Time Study, Assembly Line

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## 1. INTRODUCTION

Productivity improvement is to do the right things better and make it a part of the continuous process. According to Peter Drucker, "Productivity means a balance between all factors of production that will give the maximum output with the smallest effort". Therefore it is important to adopt efficient productivity improvement technique so as to ensure individuals and organization's growth in productivity. Work study is an important management tool to achieve higher productivity. The work study consists of two techniques Method Study & Work Measurement. Method study reduces the content of the job and work measurement investigates and reduces the ineffective time associated with a job with the establishment of the standard time. This results in efficient working operations leading to increasing productivity of that process (Pritchard, 1995).

This study focuses on one of the work measurement techniques i.e. Maynard Operation Sequence Technique (MOST) which is revolutionary from Pre-Determined Motion and Time Study (PMTS) and also concentrates how MOST is prefer as compare to other techniques like Time Study. From this study, Non-Value Added (NVA) activities, the standard time, utilization and recommendation for man power planning could be established. These result could be used for optimization of cycle time of the assembly line. There are various techniques of work measurement like Time study, Synthetic Data, Work Sampling, Historical Data Method, Analytical Estimation, and PMTS. The analysis of work using a predetermined motion time system today is performed by systematically breaking down work into very small and

distinct units called basic motions for highly repetitive, short-cycle operations, attention to detail is necessary and effective in generating valuable methods improvements.

## 2. LITERATURE REVIEW

Utilization of MOST outcomes in exact work standard, proficient limit and manpower planning. As of now more than 40, 000 individuals (mainly industrial engineers) worldwide have been trained and certified as MOST applicators. This clearly shows the effectiveness and accuracy of MOST systems. The basic problem here was to separate value added and non-value added activities from the total cycle time and consequently reduce the non-value added activities. To solve such problems Maynard Operation Sequence Technique can be easily applied as the work methods are well defined. This technique is used primarily in industries to set the standard time in which a worker should perform a task.

Abdullah R et al.(2011) in their study "Labour Utilization and Man to Machine Ratio study at a Semiconductor facility", attempted to improve productivity and reduce operational cost in MNC semiconductor industry using Maynard Operation Sequence Technique (MOST). Results showed that the current utilization of operator was as low as 47.43% for cell 1 and 41.22% for cell 2 whereas management targeted operator utilization to be at 75%. Therefore, it was recommended to increase the man to machine ratio from 1 man to 3 machines to 1 man to 5 machines for achieving the operator utilization of 75%. Elimination of Non value added activities and improve machine performance resulted in operator productivity to be improved by 22 Per cent. Thus, the study concludes that by

improving man to machine ratio through work study and by establishing a standard operating procedure productivity can be improved. (Abdullah et al., 2011)

Bondhare et al. (2016), Applied MOST method on cable assembly line for productivity improvement. Earlier, the production was 750 units with 20 workers but after applying the MOST increase in production was found as 900 units with 14 workers, which means a reduction of 6 workers saving INR 8, 64, 000/- per annum. By workplace layout modification reduced the area by 22.1 m² which helps in proper space utilization. MOST helped to establish the standard time of 160 seconds which could save 11seconds per part.

Waghambare et al. (2016) in their research study on the assembly task at one of the leading axle manufacturing company (Sharda Motor Ltd.) in India at Nashik is applied MOST with the objective of evaluation of the productivity. MOST is used to set the standard time for the activity for this. As a result, cycle time is reduced from 10.42 minute per unit to 4.326 minute per unit by reducing the number of activities from 40 to 31. Before the study productivity was 92 but after the study, productivity was enhanced as 220.

Kedar et al. (2014) in their study "Cycle Time Reduction through Toyota Production System" observed that paint shop of the toy manufacturing unit that some stations on line were overburdened while some were underutilized creating imbalance on paint line. The Basic MOST System is used for evaluating the standard time for various operations. It is seen that there is considerable variation in the work content from operator to operator from a minimum of 102 seconds to maximum of 150 seconds, even after combining some operations since it is not possible to split the activities further. The bottleneck workstations were identified and resulting in reduction of manpower from 16 to 13 i.e. 18.75%. Thus by applying Toyota Production System, cycle time can be reduced to considerable extent, hence enhancing productivity. (Karad et al. 2016)

Ankit et al. (2015) carried out their research work entitled "Productivity Improvement of Manufacturing Process of Diesel Engine by MOST Technique" at Topland Engines Pvt. Ltd. After the analysis of assembly of diesel engine manufacturing unit, it was found that most of works are done manually by workers. Industry does not have any standard time for each operation. Some operation sequences are not proper, that cause time loss. In existing layout there are lots of material movement are there in industry. So travelling distance is improper. So it takes more time from one place to another place. Proposed layout was designed so that the travelling distance of engine is reduced. By using MOST method in sub assembly department reduction of 27.66 % of total assembly time and in assembly department reduction of 18.20 % of total assembly time is achieved. In the study conducted by Vekariya & Kumar

(2015), it was observed that time study method is consuming more time as compared to MOST technique.

Ingale et al. (2014) in their study "Improvement of Productivity by New Approach-Lean Enterprise by MOST Way" emphasized the technique of work measurement by using Basic MOST. This study was carried out in a pump manufacturing industry. The existing manufacturing line is not meet with the customer demand, with available resources. By the combined approach of VSM and Basic MOST application new modified process is proposed. This study shows improvement in EWT of line by synchronisation of VSM and BASIC MOST about 40% and improvement in lead time by 15%. The hybrid optimization in which synchronisation of Lean and MTM occurs is called Lean Enterprise by MOST Way.

### 3. MAYNARD OPERATION SEQUENCE TECHNIQUE (MOST):

MOST was developed by H.B. Maynard in 1970. It is one of the revolutionary predetermined Motion and Time Study techniques for work measurement. It allows the system to measure the work with the help of method steps and sequence models. The time units used in MOST are based on time measurement units generally known as TMU. (Maynard et al., 2012)

1 TMU = 0.00001 hour = 0.0006 minute = 0.036 second

1 hour = 100, 000 TMU, 1 minute = 1, 667 TMU, 1 second = 27.8 TMU

#### 3.1 Types of MOST Systems:

MOST is designed in multilevel to suit the various needs of industries and depending upon the type of Work content (Hodson & William 1998). There are basically 4 types of MOST Work Measurement Systems viz. Basic-MOST which is used for medium-cycle, repetitive/non-repetitive work; Mini-MOST is used for short-cycle, repetitive work; Maxi-MOST is used for long-cycle, non-repetitive work; while Admin-MOST is used for medium-cycle, repetitive/non-repetitive administrative work. (Maynard et al., 2012)

**a) Basic MOST:** Basic MOST is by a wide margin the most ordinarily utilized variant of MOST. At the intermediate level, exercises that are prone to be performed more than 150 however under 1500 times each week ought to be analyzed with Basic MOST.

Following three sequence models have been established:

- i) General Move Sequence
- ii) Controlled Move Sequence
- iii) Tool Use Sequence

**b) Mini MOST:** At the most detailed level, Mini-MOST gives the most exact technique analysis. As a rule, this level of detail and accuracy is required to analyse exercises prone to be repeated indistinguishably more than 1500 times each week.

- It is developed to meet more accuracy
- Mini Most is more detailed and consumes more time
- Hence it is used in only selected cycles which are identical and repetitive.

**c) Maxi MOST:** At the highest level, Maxi MOST is utilized to analyses exercises that are liable to be performed under 150 times each week.

- In long, non-repetitive cycles, Basic MOST would record unnecessary details which are meticulous and painful.
- Hence at the highest level, Maxi MOST is used to analyses operations that are likely to be performed fewer than 150 times per week.
- An operation in this category can range from 2 minutes to several hours
- Maxi MOST capture those operation cycles that has a lot of variation after each cycle.
- Maxi MOST is used for long cycles.

### 3.2 Advantages of MOST:

As compare to other methods, the advantages of MOST are:-

- Cost reduction
- Reduction in paperwork

- Improve productivity
- Easily identifies NVA activities
- Provides time standards
- Offers precision to  $\pm 5\%$  with a 95% certainty level
- Applicable for every type of industry
- Encourages method development and improvement

## 4. METHODOLOGY

The basic problem here was to separate value added and non-value added activities from the total cycle time and consequently reduce the non-value added activities. To solve such problems MOST can be easily applied as the work methods are well defined. The frequency occurrence numbers ranges from 150 to 1500 and accuracy of  $\pm 5\%$  with a 95% confidence level so this problem falls under the category of Basic MOST work measurement system. The Basic MOST work measurement technique comprises the following sequence models:

**4.1 General Move Sequence-** when objects are moved from one location to another manually and freely through the air, the move is termed as General Move. A General Move can occur in various ways. The activity sequence is made up of 4 parameters.

**A** - Action Distance (mainly horizontal)

**B** - Body Motion (mainly vertical)

**G** - Gain Control

**P** - Placement

These parameters can be arranged in a logical sequence which defines events or actions that always take place in a prescribed order when an object is moved from a point to another. The General Move Sequence Model is most widely used a model which may be defined as:

<b>A</b>	<b>B</b>	<b>G</b>	<b>A</b>	<b>B</b>	<b>P</b>	<b>A</b>
Action	Body	Gain	Action	Body	Placement	Action
Distance	Motion	Control	Distance	Motion		Distance

**4.2 Controlled Move Sequence-** this is used for the controlled movement of an object i.e. movement of an object when it remains in contact with a surface or is attached to another object during the movement for example sliding an object over another, operating a lever. Activity sequence in this case is made up of 6 parameters three of which viz. A, B and G are same as in the above case. The other 3 are as follows:

<b>M</b>	<b>X</b>	<b>I</b>
Move Controlled	Process Time	Alignment

**4.3 Tool Use Sequence-** it is used in cases where common hand tools such as screwdriver, hammer, wrench, ratchet etc. are used. Normally it is a combination of General Move and Controlled Move activities and does not define a third basic activity. In addition to the parameters mentioned in above two sequences, the tool use sequence model includes the following parameters:

F	L	C	S	M	R	T
Fasten	Loosen	Cut	Surface	Measure	Record	Think

### **MOST Procedure:**

An overview of MOST procedure is as follows:

- Watch job or task
- Determine sequence(s) to use
- Determine index values
- Add index values to determine TMU
- Multiply TMU by 10
- Convert TMU to seconds, minutes or hours

On the basis of the MOST analysis, some of the scopes of improvement in the area of concern i.e. bottleneck stations of the assembly line were identified and possible solutions for incorporating the advanced resources were proposed accordingly.

### **5. DATA COLLECTION AND ANALYSIS:**

In order to evaluate the problem with the existing working methods and procedures, the data relevant to the existing work methods and techniques in the assembly line was collected and evaluated which helped in setting up base for MOST study. There were 15 stations including 2 quality gates in the HCV engine assembly line. These stations were observed and the average operational time per day corresponding to each station was recorded by a mobile video.

The values were recorded for consecutive days in a week depending upon station to station. These values were then compared to the takt Time. This comparison clearly shows which stations were performing up to the mark and which stations were under-performing. MOST method was then applied to the under-performing stations of assembly line. By applying MOST, the non-value added (NVA) activities were separated from the value added (VA) activities, which further helped in finding out the root causes of various NVA activities.

Bottleneck station activities are first divided into elemental activities and then applied MOST method on that activity and categorize the activities into the Value-added, Semi-value added and Non-value added activities which are shown in appendix.

### **Illustration of MOST method:**

Let us consider the operation “Fuel Filter and Alternator Assembly”.

STEP-1: This operation will be divided into following sub operations -

- Inlet manifold fitment
- common rail fitment
- Fuel filter fitment
- Injector harness
- Injector harness clip
- Alternator oil inlet hose
- Alternator mounting
- Alternator oil drain hose fitment
- Alternator support bracket 1
- Dip Stick guide mounting

STEP-2: Now, let us consider the sub operation “Fuel filter fitment” and this sub operation will be further divided into following elemental activities

- Walk two steps towards trolley
- Pick the fuel filter
- Walk two steps return to engine
- Pick the three bolt
- Mount the fuel filter with three bolts manually
- Pick the gun
- Apply the torque on 3 bolts
- Rest the gun

STEP-3: To determine the Index values for each elemental activity the standard charts are used which were devised by H. B. Maynard. There are three such charts which aid us to determine the Index values related to all the elemental activities. First is for General Move, second is for Controlled Move and the third is for Tool Use. These charts are depicted on the next page. So, using these charts we can get the Index values for the sub operations mentioned in step-2.

STEP-4: Add the Index values for each sub operation. Multiply the Index value by 10 to get the TMU or time measurement unit. And then multiply the TMU by 0.036 to get the time value in Seconds which can further be converted in minutes and hours.

Table-1 shows the elemental activities, their corresponding index values, TMU or time measurement units and operational time (in seconds) for above illustration.

**TABLE 1: Elemental activities, their corresponding index values**

Elemental Activities	Move	Index Values	TMU	Time (in sec.)	VA/SVA/NVA
Walk two steps towards trolley	G	A3+B0+G0+A0+B0+P0+A0	30	1.08	NVA-W
Pick the fuel filter	G	A1+B0+G3+A0+B0+P0+A1	50	1.8	SAV
Walk two steps return to engine	G	A3+B0+G0+A0+B0+P0+A0	30	1.08	NVA-W
Pick the threebolt	G	A1+B0+G1(3)+A0+B0+P0+A1	50	1.8	SAV
Mount the fuel filter with three bolts manually	C	A1+B0+G1+M10+X16+I0+A1	290	10.44	VA
Pick the gun	G	A1+B0+G1+A0+B0+P0+A1	30	1.08	SAV
Apply the torque on 3 bolts	T	A1+B0+G1+A1+B0+P1+F6(3)+A0+B0+P0+A1	230	8.28	VA
Rest the gun	G	A1+B0+G1+A0+B0+P1+A1	40	1.44	SVA

Legends:

G- General Move

C- Controlled Move

T- Tool Use

VA- Value added activity

SVA- Semi value added activity

NVA-W - Non value added activity (walk)

Table-2 shows that maximum 2.81 min can be save on fuel filter assembly station through MOST and approx. 01 min in all the station including LH and RH side. Through this study it can be concluded that by the use of MOST method significant time can be saved on the assembly line which ultimately reduces the cycle time.

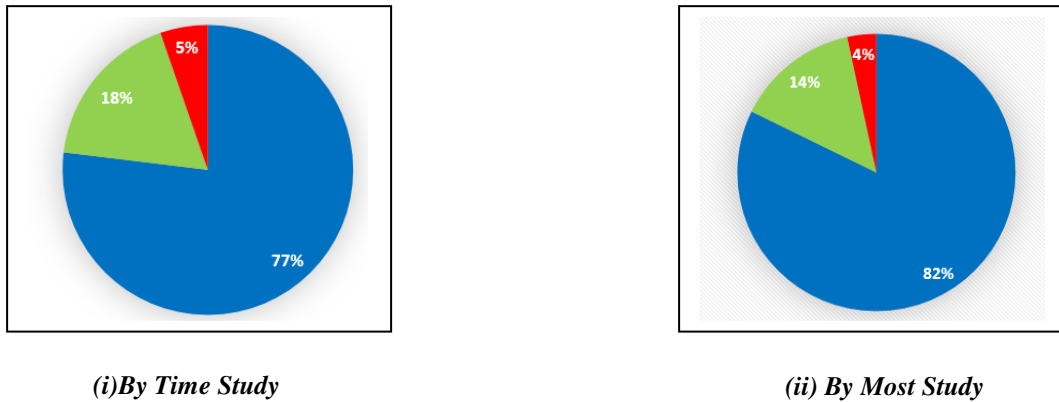
**TABLE 2: Comparison of Time Study and MOST study**

Station	LHS			RHS		
	Time Study	MOST	Time Saved	Time Study	MOST	Time Saved
Flywheel Station	8.26	7.11	1.15	10.03	8.46	1.56
TG case Station	11.05	9.91	1.13	11.11	10.03	1.08
Injector and oil cooler assembly station	10.28	8.96	1.31	14.35	12.81	1.54
Fuel filter and alternator assembly	14.6	11.79	2.81	3.7	2.64	1.06
High pressure pipe	14.15	12.04	2.10			

## 6. RESULTS AND CONCLUSIONS

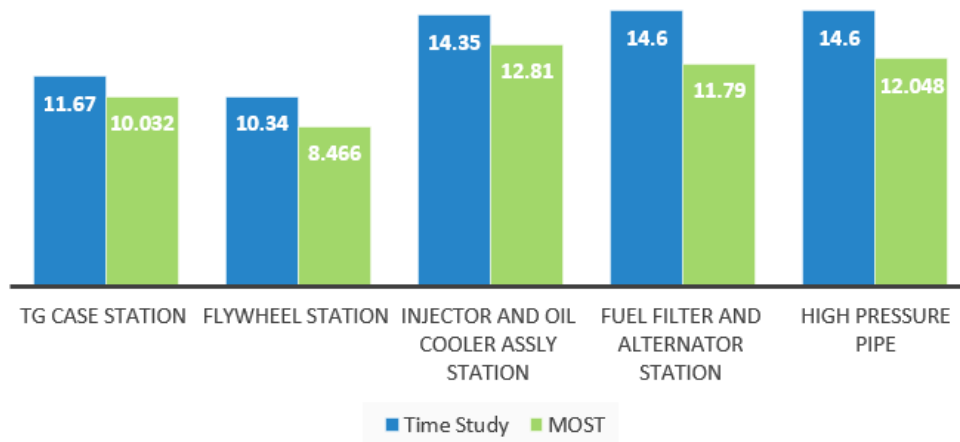
In the HCV engine assembly line it has been found that through MOST method the bottleneck stations can be optimized with labour requirement as well as takt time can be synchronized with the station cycle time by eliminating the NVA activities and taking MOST as a standard for time for labours.



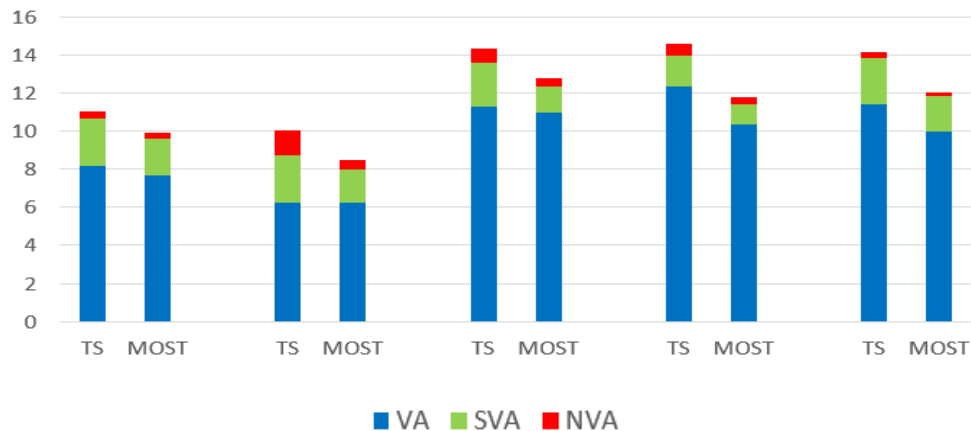


**Fig. 1. VA and NVA obtained at HCV Engine Assembly Line**

The figure-2 shows the comparison between time study and MOST study in which 1.13 min, 1.15 min, 1.31 min, 2.81 min, 2.10 min are saved by MOST method on TG case station, flywheel station, injector and oil cooler assembly station, fuel filter and alternator assembly station and high pressure pipe assembly station respectively



**Fig. 2. The VA, SVA and NVA activities comparison at five bottleneck stations.**



**Fig. 3: VA, SVA and NVA activities comparison**

## Productivity Calculation:

### By Time Study-

Total time available per shift = 450 min or 7.5 hr  
Maximum Station Time or Cycle time = 14.6 min  
Total unit Produced per Shift =  $450/14.6 = 30.82$  units per shift  
Labour productivity (in terms of hours)  
= Total quantity produced/ Actual man hours required to produce that quantity =  $30.82/7.5 = 4.10$

### By MOST Study-

Total time available per shift = 450 min or 7.5 hr  
Maximum Station Time or Cycle time = 12.81 min  
Total unit Produced per Shift =  $450/12.81 = 35.12$  units per shift  
Labour productivity (in terms of hours)  
= Total quantity produced/ Actual man hours required to produce that quantity =  $35.12/7.5 = 4.68$   
Increase in Labour Productivity =  $4.68 - 4.10 / 4.10 = 0.142 = 14.2\%$

As per the calculation, it can be concluded that MOST technique is best suited for work measurement as compared to the Time study. By applying MOST on the assembly line it can help to increase in the productivity by 14.2%.

## 7. CONCLUSIONS

This study was aimed to improve the productivity by applying MOST. As far as this study is concerned, it is focused on the five bottleneck stations. TG case and flywheel station was the under-performing stations of the assembly line. The study was done by disintegrating the operations into simple elemental activities and then assigning index values to those elemental activities to get the theoretical cycle time. Through MOST, the inefficient work methods and inefficient layout of the work place were easily highlighted. The cycle time of assembly line calculated by MOST for engine assembly came out to be 12.81 minutes which was considerably less than the time study.

The MOST technique that has been applied in engine assembly line has shown some great result by reducing the cycle time. Through MOST the NVA can be easily detected by seeing the high index values and then by finding ways to reduce it thus it is very interactive process in which problem identification can be easily done. The study shows that out of total time 5% of time is NVA. Some basic NVA seen is in bending and walk so this can be eliminated by

finding some ways ergonomically designed to make everything reachable to the worker and unwanted delay can be reduced. When a workplace is ergonomically arranged, the duration after which workers experience fatigue will be delayed. Sometimes lack of supervision also led to idleness amongst workers. With the help of results shown by this study the Non Value Added activities are identified in HCV engine assembly line and were rectified to increase productivity.

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# Critical Review of Productivity Improvement for Manufacturing Industries and Related Issues

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**Abstract:** The instant paper critically examines the literature contributed by various authors practicing in the field of productivity enhancement and also discusses the growth paradigm as well as role played in the recent few decades. The competition among the producers has become stiff and profit margins have gone slender. The need of the hour is to stimulate overall productivity. The primary emphasis is on the manufacturing industries with complex systems comprising many subsystems, whose individual performance affects the total productivity of the Plant. Hence, the overall productivity might be recognized as the performance indicator of the business, where the global market scenario is swiftly changing along with the rapid variations in the technology. The relevant productivity improvement tools comprising of qualitative and quantitative approaches will provide the well-organized guidelines for supervisors and practitioners right from the design level to the manufacturing stage. Authors presumed that different tools for productivity improvement would be providing a trade-off between business objectives and financial investment.

**Keywords:** Total Productivity; Cycle Time; Manufacturing Cost; Material Productivity; Inventory; Labor Productivity

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## 1. INTRODUCTION

The word 'Productivity' has become such a common name as by and large everyone talks about it. Even then "productivity" is interpreted differently by different persons. As a consequence, it varies from efficiency to effectiveness, to rates of turnover to output measures, to measure satisfaction of consumer, to intangibles such as a disruption in workflow and to further intangibles such as loyalty, pride, morale and job complacency. Productivity is an efficiency measure with which resources including primarily workforce and material, are converted into useful goods and intended services with a view to enhance values. The rapid rate of financial growth can be ensured through improved production rates and higher productivity holistically in entire business domain.

The workforce productivity (labor) is of prime importance amongst all inputs / resources and plays a vital role in determining the overall economic growth of an organization and finally that of nation. Besides the level of human skills, the quality of raw materials and the technology employed are also responsible for productive human resources. The productivity ratio is an indicator of efficiency with which an enterprise or company converts its resources available (inputs) into finished goods or services (outputs). If the goal is to increase productivity, this can be done by producing more output with the same level of input. Productivity can also be increased by providing the same output with less inputs. One problem with trying to measure productivity is that a decision must be made regarding identifying the inputs and outputs; how they will be measured. It is

relatively easy when the productivity of an individual is considered, but it becomes difficult when productivity to be measured involves a whole company or a nation [1].

The meaning of productivity is complex because it is both a technical and managerial concept. Productivity is a matter of concern to government bodies, trade unions and other social institutions not heeding the disagreements over its conceptualization by different groups and individuals. Productivity is a test of how much input is required to produce a given output, i.e., the ratio output to input. The productivity of a production system is analogous to the efficiency of a machine.

Productivity defined as human efforts to produce more and more with less and fewer inputs of resources as a result of which the benefits of production are distributed among a maximum number of people. Productivity is a constant adjustment of economic and social life to varying circumstances. It is the continual attempt to apply new methods and techniques (**European productivity council**). Productivity means a balance between all factors of production that will give maximum output with the smallest effort (**Peter Drucker**). Total productivity is a ratio of aggregate output to aggregate input (**ILO**). The term productivity defined as the ability of an organization or company to convert available resources into profitable services or goods. The concept of productivity and production are entirely different. Production refers to total output while productivity is a relative term wherein output always expressed regarding input. Production means the

output in the form of money where as productivity is the efficiency of the production system.

## 1.1 ESSENTIAL FORMS OF PRODUCTIVITY

### 1.1.1 Partial Productivity

It is the ratio of output to one class of input. For example, labor productivity (the ratio of output to labor input) is a partial productivity measure. Similarly, capital productivity (the ratio of production to capital input) and material productivity (the ratio of output to material input) are examples of partial productivities.

### 1.1.2 Total-Factor Productivity

Total factor productivity is the ratio of net output to the sum of associated labor and capital (factor) inputs. The net output means total production minus intermediate goods and services purchased.

### 1.1.3 Total Productivity

Overall productivity is the ratio of total output to the sum of all input factors. Thus an overall productivity measure reflects the joint impact of all the contributions in producing the output.

## 2. LITERATURE SURVEY AND REVIEW

**Gunasekaran and Cecille (1998)** concluded that small and medium enterprises (SMEs) have always played a fundamental role in economies of entire major industrial societies regarding both Gross Domestic Product as well as employment levels. In the recent past, most of the new manufacturing ideas and technologies implemented on a massive scale in manufacturing industries for productivity enhancement.

**Arditi and Mochtar (2000)** conceded that cost limitation, scheduling, design techniques, quality control and preparing work force are essential purposes perpetually sensed over the decades as stimulating productivity.

**Aw et al. (2001)** the excellent rate of turnover could be contributive for the enhancement of the industrial productivity if resources are exchanged from more skilled manufacturer to less efficient one.

**Sheth and Sisodia (2002)** Productivity enhanced by reducing the cycle time and statistically controlling the process.

**Goldar (2004)** opposed the findings of numerous preceding studies; a modern research about productivity trends in Indian production by Unel (2003) settled that Total Factor Productivity growth accelerated after 1991 economic reforms.

**Gorg and Hanley (2005)** Outsourcing of materials for plants with low export intensities substantially increased the productivity.

**Bond and Galinsky (2006)** Creating efficient workplace for employees, rendering them accountable and supported at work by handing over more responsibility to them, ensuring more competency, better satisfied with their jobs, more dedicated to employers, possibly more productive, likely to increase retention and exhibiting better mental health, resulting in higher productivity.

**Yazid (2007)** productivity improved using single piece flow technique. Numerous data were taken and prove the growth by ensuring single piece flow approach.

**Natarajan and Duraisamy (2008)** An econometric investigation of determinants of the total factor productivity growth (TFPG) illustrates that literacy, proprietorship; farm growth and availability of infrastructure significantly affect total factor productivity increase in the area.

**Walia et al. (2009)** the paper exhibits improved fixturing enhanced the productivity by improving surface roughness properties and vitally reducing the processing time.

**Dash et al. (2010)** stated that after the pre-reform and post-reform decades, hardly any attempt to ascertain the sources to improve overall industrial performance carried out. This study estimated the total factor productivity growth of the manufacturing industries of different states of India.

**Sivakumar and Saravanan (2011)** allocation and use of identified resources performed a significant role in the industry for the improvement of quality and productivity.

**Hemanand and Amuthuselvan (2012)** the automotive industry is undergoing rigorous competition and striving to devise techniques to reduce manufacturing cost and waste be falling. Carrying out lean manufacturing approach in-process inventory declined to accelerate the production process, consequently applying the resources entirely in the form of the machines and workforce the productivity raised.

**Trimble et al. (2013)** presented the outcomes of a study undertaken in investigating the usefulness and impact of manufacturing productivity improvement strategies within automotive component suppliers. The result of a survey for 161 automotive suppliers presented. The paper highlights the adoption of continuous improvement tools and comprehensive methodologies.

**Medda and Piga (2014)** Methodology corrects simultaneously for the endogeneity and the selectivity preferences introduced by the use of a firm's R&D as a regressor. The evidence suggests that a company's involvement in R&D activities accounts for significant productivity gains.

**Saleeshya and Bhadran ( 2015)** With curtailed lead time presumed for manufacturing the goods, productivity improvement stimulated by recognizing different types of waste cached up incorporating various production steps and picking the decisive one.

**Carrington et al. (2016)** the paper formulates a substitute framework which implements incentive modulation to allocate grants to universities to improve their productivity.

**Skorupinska and Torrent-Sellens (2017)** the major finding emerged from the study is wage which is the principal primary determinant of labor productivity. Moreover, the relationship between ICT and productivity established indirectly.

## 2.1 Concluding Remarks

From the current literature review, it can be well concluded that productivity has an essential role to play in manufacturing companies. Since productivity directly influences manufacturing cost and efficiency, hence the need of the hour is to raise total productivity which comprises labor productivity, material productivity, and the Machine productivity without compromising on **Quality, Functions, Purpose and Safety**. Resources available in the industry are to be optimized using the modern manufacturing techniques. Several known challenges related to study and measurement of productivity in manufacturing industries have already been discussed in details.

## 2.2 Gaps Observed from Literature Review

Almost all the researchers suggest a general solution to problems of all type of industries, having the diverse working environment. The researchers have worked for primary, secondary and tertiary industries, especially industries like manufacturing, agriculture sector, weaving & apparel, automobile, and chemical industries. To eliminate discrepancies noted / observed during the review of the above-cited publications and to effectively disseminate the scope of manufacturing productivity, the under mentioned aspects need to be taken care off. The need of the time is to apply tremendous potential on increasing the productivity of manufacturing industries. Most of the researchers focus on increasing partial productivities, but the **foremost need of the times** is to increase the overall productivity i.e **Holistic Productivity or Umbrella Productivity**.

- By and large, the researchers gave the methodology to improve the productivity of a single product which does not serve the entire purpose, while the need of the current scenario is to increase the aggregate productivity of various products simultaneously in a multi product industry.

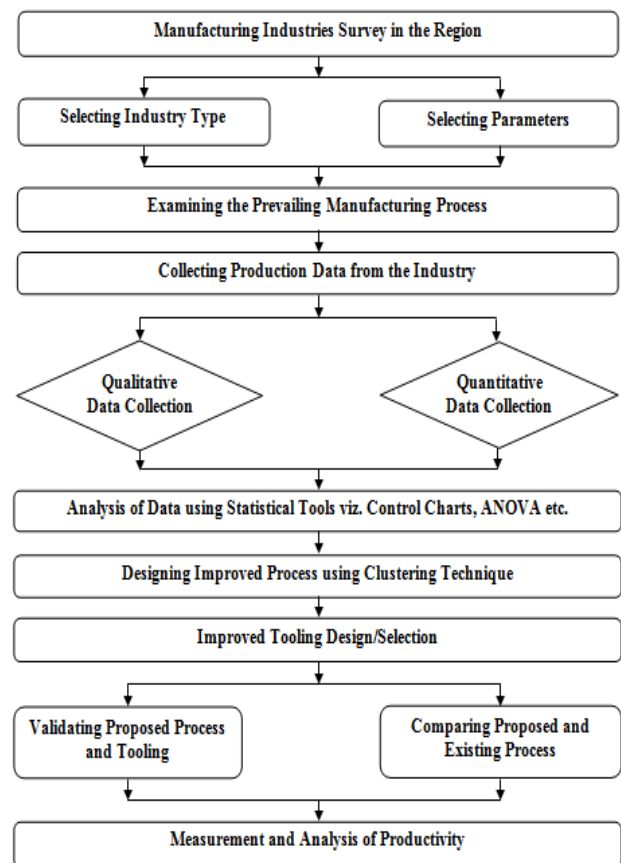
- Different authors explained methods for improving the productivity of a single workstation in the company at a time, but the productivity improvement of multi work-stations is the first need.
- Maximum algorithmic approaches used by authors, focused mainly on reducing flow distance to minimize the cost of material handling (single objective), not considered multi-objective functions.

There is still need for research in multi-objective functions such as reducing shipping cost, lead time, space required, the number of machines needed and labor cost.

From the research gaps discussed above, it is concluded that still there is a scope for research on the productivity improvement problems related to manufacturing industries and the methods proposed should be capable of improving the existing process and consequently increase the productivity.

## Methodology Proposed for Research

Figure 3.1 exhibits the suggested methodology for enhancement of manufacturing productivity.



**Fig. 3.1. Flow Chart for Proposed Methodology for Research Work**

### 3. CONCLUSION AND FUTURE SCOPE

The critical review of the available literature highlights the various productivity improvement tools and techniques applied in different phases of manufacturing in industries to minimize the production cost which would result in competitive pricing of the product. The utilized tools are newly developed models, softwares, and various techniques applicable to the design of improved process as well as the operational requirement. The literature reviewed reflects some limitations and implications for providing the broad scope for productivity improvement. Finally, it is concluded that in future a more *Holistic or Umbrella approach*/research methodology is desired to ensure minimal production cost to improve upon the manufacturing productivity. The authors feel that still, there is an ample scope of research for new methods to be devised to stimulate production coupled with high productivity to maximize profits and position the brand in this dynamic business scenario.

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# Critical Success Factors of Kaizen Methodology

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**Abstract:** Manufacturing industries are highly dynamic in nature and functioning. There is always fluctuation in demand, change in orders, change in clients, change in vendors, change in design, machine utilization, operator efficiency, change in machine infrastructure, accuracy level and maintenance conditions. Human nature tendency is to repeat the concepts until it is asked to change. Kaizen means change for better. Manufacturing system consists of established operation processes. There is always a scope for betterment or improvement in manufacturing processes. The improvement is aimed for reduction in manufacturing waste, reducing in idle time and improvement in quality.

This study is focused on philosophy of Kaizen concept. Key success factors of Kaizen are reviewed for better understanding and implementation for users. Many researchers have contributed their work for improvement in manufacturing using Kaizen methodology. This paper is focused on critical success factors of Kaizen methodology, based on previous case studies.

**Keywords:** Kaizen, Continuous Improvement

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## 1. INTRODUCTION

Kaizen is Japanese word, which means "change for better". The word does not interpret as either continuous or philosophy in Japanese dictionaries. The word refers to any improvement in the existing manufacturing system, may be one-time or continuous, large or small, in the same sense as the improvement only. However, Japan has given the common practice of labeling industrial or business improvement techniques with the word "kaizen", particularly the practices spearheaded by Toyota is typically applied to measures for implementing continuous improvement, especially those with a "Japanese philosophy". The discussion focuses on such interpretations of the word, as frequently used in the context of modern management discussions.

Two kaizen approaches have been distinguished:

- Flow Kaizen: The approach is oriented towards the flow of materials and information, and is often identified with the reorganization of an entire production area, even entire company.
- Process kaizen: This approach is focused on the improvement of individual workstands. Therefore, improving the way production workers do their job is a part of a process kaizen.

The use of the kaizen model for continuous improvement demands that both flow and process Kaizen are used, although process Kaizen is used more often to focus workers on continuous small improvements. In this model, operators mostly look for small ideas which, if possible, can be implemented on the same day. This is in contrast to traditional models of work improvement, which generally

have a long lag between concept development and project implementation. In the traditional model, the time between concept development and project implementation is very long. In the kaizen model, workers mostly look for small ideas and improvements which can be implemented on the same day.

## 2. LITERATURE REVIEW

Many researchers have contributed their research work in Kaizen methodology. Major contributors are also concerned with quality management. Massaki Imai has conveyed that "Kaizen is a mindset. Many lean practitioners put kaizen in their tool box, but those who strive to live it, each day are the people who are making a difference in people's lives." According to Imai, Kaizen is a continuous improvement process involving every one, managers and workers.

A.P. Puvanasvaran, Robert S.T. Kerk and A.R. Ismail have stated in their research that Kaizen plays an important role in eliminating losses and waste either in production or nonproduction activity. A slight improvement of even 1% is considered a good improvement in workplace. The most important thing in kaizen is make the improvement continuously. To make the continuous improvement in company, firstly is to set the right mindset.

Mayank Dev Singh and et al, have mentioned that implementing 5 S methodology in the existing production system is a stepping stone in the implementation of Kaizen. Other benefits are derived as, searching time reduced by 6-8 minutes and it also improves aesthetic of workplace.

Nadia Bhuiyan and Amit Baghel have mentioned in their study that it is also generally agreed that Continuous

Improvement (CI) and Quality Management (QM) programs go hand in hand as they seek to achieve excellence through improvement.

JigneshBhoi, Darshak Desai, RohitPatel (2014) have stated that there is a great scope of research is possible for new researchers in continuous improvement domain. So more research is required which can improve the awareness aspects. Selection of key factors are highly important for the success of the Kaizen philosophy in most of the manufacturing industries for successful implementation of Kaizen.

Wickens (1990) highlights the impact of the teamwork on Kaizen. Teamwork and commitment do not approach from involving the representatives of employees, but from direct contact and communication between the individual and his boss.

Hammer et al. (1993) describes that Kaizen creates process-oriented thinking. Hence processes to be improved before superior results are obtained. Improvement can be separated into CI and innovation.

Bassant and Caffyn (1994) define the CI concept as an organization-wide process of focused and sustained incremental innovation'. These processes of incremental innovation are supported by various tools and techniques.

Deming (1995) describes that organizations are developed at a greater rate than at any time in recorded history. Thus a highly competitive and constantly changing environment recommends major managerial changes as well as challenges. Many managers have squeezed the philosophy of a Kaizen to effectively tackle this situation.

Summarizing the literature review:

Kaizen methodology is for small and continuous improvement. It may start with 5 S implementation. It requires involvement of all employees, may be through quality circle. It is focused to process improvement for improving productivity, simplicity in manufacturing process. It reduce several delays of production process. It improves morale of employees. Kaizen is helpful in improving productivity and quality.

### 3. KAIZEN PHILOSOPHY

Kaizen Philosophy implements good housekeeping and workplace organization. It Identifies and eliminate all activities that are waste in production system. This also promotes implementation of standardization. The philosophy involves current state and future state mapping, solving manufacturing related problems, expose of hidden problems, value added time, lead time, waste, variation, and constraints. Kaizen philosophy says that; becoming lean is a journey, and will not be possible to without initiative.

### 4. ELEMENTS OF KAIZEN

There are mainly 5 elements of Kaizen process. They are mentioned as: Quality focus, Human effort, Total involvement, Willingness to change, and Communication. Any element can be focused for seeking improvement in the manufacturing organization.

### 5. KEY KAIZEN APPROACHES

Good Housekeeping ("5S"), Waste ("Muda") Elimination, Standardization and Continuous improvement.

### 6. TOOLS AND TECHNIQUES FOR KAIZEN

There are many tools and techniques under the Kaizen umbrella. These tools can be used for improvement process. Quality Improvement, Just-In-Time, Kanban, Zero Defects, Small Group Activities, Problem Solving Groups, Productivity Improvement, New Product Development, Customer Focus, Quality Circles, Suggestion Ideas System, 5S, TPM, AM, Continuous Flow, TQM & TQC.



Fig. 1. Kaizen Tools (Kaizen Umbrella)

### 7. MANAGERMENTS' ROLE IN KAIZEN IMPLEMENTATION:

Management initiative is important in kaizen implementation. Positive role of management is very essential. Management has to communicate the need to change by taking involvement, Demonstrate personal commitment to process improvement, Educate and train staff in Kaizen concept, Plan and manage the improvement process.

### 8. BENEFITS OF KAIZEN

Implementation of Kaizen brings many advantages to the organization. Empowers employees, enriches the work



experience and brings out the best in every person, Promotes personal growth of employees and the company, Improves quality, safety, cost structures, delivery, environments, throughput and customer service/satisfaction, Provides guidance from employees, and serves as a barometer for leadership.

## 9. SCOPE OF KAIZEN

Any improvement can be divided into two groups. They are Kaizen and innovation. Kaizen signifies small improvements as a result of ongoing efforts. Innovation involves a drastic improvement as a result of large investment of resources in new technology or equipment. Innovation decisions involves drastic change in the production system, hence it requires involvement of top management and middle management employees. Kaizen requires involvement of workers and supervisors; since they are highly concerned for improvements. Machine conditions are important for maintaining quality and accuracy in products. Maintenance related decisions should be taken by shop floor related employees, in order to take utmost care for planned maintenance. This is shown in figure 2.

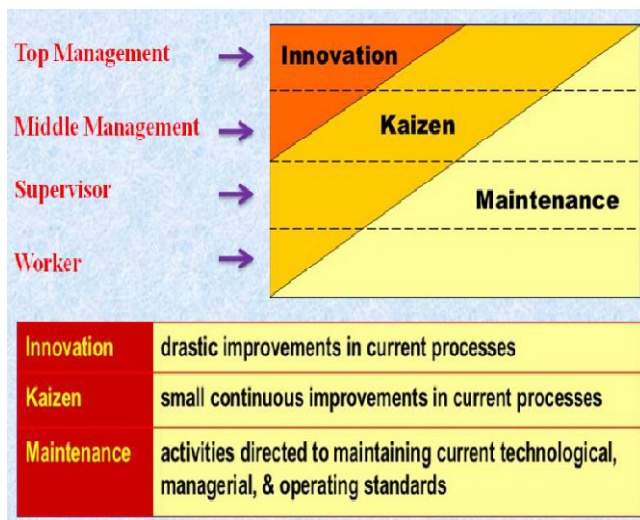


Fig. 2. Scope of Kaizen

## 10. KAIZEN BLITZ AND MINI KAIZEN:

The Kaizen Blitz or Kaizen event is a focused, intense, short term project to improve a localized process. Substantial resources like fundamental concepts of engineering, maintenance, cell operators, and others are available for immediate deployment. The kaizen blitz is a localized and smaller scale improvement.

Mini-Kaizen: Mini kaizen is very small scale improvement. This is a slow accumulation of many small developments in process and quality. Small scale

improvements are easier and faster. The risk are low, because they generally have limited effect.

## 11. CRITICAL SUCCESS FACTORS

There are many key factors for successful implementation of Kaizen philosophy. In the present study following critical success factors are identified to implement Kaizen successfully in the manufacturing organization.



Fig. 3. Critical Success Factors for Kaizen

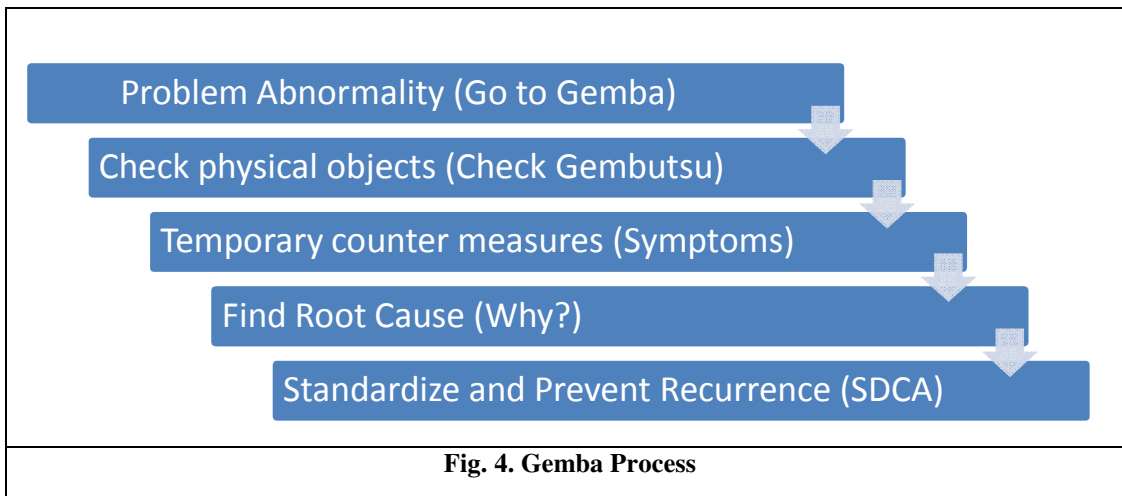
- 1. Management commitment:** Top management must express commitment in many different ways, in implementing Kaizen and it must take every opportunity to: preach the message, become personally involved in following up the progress of Kaizen, and allocate resources for successful implementation. Management should also provide education and training to staff about Kaizen. Management must support Kaizen improvement and it should take review progressively by measurement of various parameters of production system. In any case, management must manage resistance to change amongst various staff. Finally management should also recognize participation of staff in continuous improvement process.
- 2. Focus on the goal:** Kaizen may be implemented by two approaches. First is to improve flow of material and information about manufacturing status (communication) and other is eliminate process waste to reduce cost of manufacturing. Flow improvement can be made by adding automation in material

movements and eliminating manual movement of material components. Process waste can be reduced by implementing lean manufacturing concepts. This approach may include identification of waste by observation and available baseline data and finding better solution for reducing process time.

3. **Aligned focus from the top to the bottom:** Top level employees should be given more weightage for responsibility in improvement aspect. They should be involved in decision making in brain storming session in order to get better improvements in manufacturing process. They will be working as part of solution / improvement process.
4. **Allocate the proper resources:** Manufacturing process includes machine resources, man power resources, and many infra-structure resources. These resources should be allocated appropriately to each

department and individual employees. The resource utilization should be more effective and productive.

5. **Gather baseline information and measure results:** The improvement is always with reference to base line performance of the manufacturing system. Hence, for every manufacturing process record should be generated and they should be evaluated by management for measurement of machine efficiencies, operator efficiency, rejection rate, rework rate etc.
6. **Go to the Gemba:** In case of manufacturing system, the *gemba* is the factory floor. In lean manufacturing, the idea of *gemba* is that the problems are visible, and the best improvement ideas will come from going to the *gemba*. A Gemba walk can be used by varying levels of seniority to observe processes all the way up the value stream. It can be tasked to capture a range of different information.



Fundamentals of Gemba House are as mentioned as: Basic rule is to build self-discipline in the organization. Other fundamentals are as 1. Reward small steps 2. „Catch” people at the good work 3. Stay open to questions 4. Develop positive thinking culture 5. Allow the standards improvement process become widespread 6. Carry out evaluation 7. Encourage customer involvement 8. Implement the suggestion system 9. Create quality circles 10. Build a reward system 11. Clearly communicate your expectations.

7. **Get as many people involved as team:** In kaizen process almost all employees should be involved and they should be part of team. It may be quality circle or any other activity for their involvement in continuous improvement process. Overall team should work cohesively to get better improvement and individual suggestions and contribution should be appreciated.

Team members should work with open mind for better growth of the organization. The morale of employees will be improved.

8. **Understanding of Kaizen concepts:** All employees should be given training on Kaizen concepts. They should be able to identify manufacturing problems and they should apply Kaizen concept as a team. Convention way of thinking should be avoided and better flexibility should be created. Training will be helpful in knowledge transfer in effective way.
9. **Effective use of Kaizen methodologies:** There are many types of Kaizen process. Kaizen blitz, Mini Kaizen (Daily events), Kaizen events, etc. Depending on type and size of problem Kaizen methodology should be selected. There are many tools and techniques used for Kaizen. Appropriate selection of technique should be made.

## 12. REVIEW OF CASE STUDIES:

Name of Organization	Sandvik Asia Pvt. Ltd.
Problems identified	More waste, waiting time, poor arrangement, Abnormality
Approach	Lean Manufacturing, Reduce Abnormality
Kaizen Tools used	5 S, Kaizen, Visualization
Results in improvement	Search time reduced by 6- 8 min., Reduced man motion, Improved aesthetics, Improved safety, saving of damaged cost

Name of Organization	Poland in Bielsko-Biala
Problems identified	Lack of descriptions on containers, lack of marking of doorstep of entering door to warehouse of cranes, lack of space for spare parts, poor light in weld room etc.
Approach	Continuous process of improvement which engages top management of a company, management staff and all employees.
Kaizen Tools used	Brainstorming, Ishikawa diagram, matrix diagram, 5S tool, and others, help to identify problems (causes of problems) Continuous improvement
Results in improvement	20% improvement in productivity

Name of Organization	The company HV Axles Ltd. (Early it used to be the Axle Division of Telco (Tata Engineering, Jamshedpur))
Problems identified	Number of operators like to be exceeds in assembly line, Less Production efficiency Excess number of operators
Approach	Kaizen Approach to meet the target/Productivity from 210 axles per shift (8 hours) to 300 axles per shift
Kaizen Tools used	TAKT Time to reduce waste and improve operator's efficiency
Results in improvement	Results are reduction in throughput time, addition of workstation to meet the Takt time, and elimination of unnecessary operations, activities and workstation.

Name of Organization	Denso Engine Parts
Problems identified	Piking materials, Muda of transport, Line feeding
Approach	New Job process and planning, Line design suitable to multiple use
Kaizen Tools used	Value Stream, Line balancing
Results in improvement	Man power cost reduced to 25% Space saving by 50%

Name of Organization	Promet
Problems identified	Less productivity, High Waste of raw material
Approach	5 S, Quick changeover, Kanban, Andon
Kaizen Tools used	Layout improvement Assembly cells layout
Results in improvement	Productivity improved by 22% Product family concept, More manufacturing sites

Name of Organization	Unilever – New equipment Development
Problems identified	Too long commissioning of projects
Approach	Design review, Maintenance prevention
Kaizen Tools used	Methodology Analysis in installations
Results in improvement	Short commissioning period, No schedule delay, Project cost below budget

Name of Organization	ALUMAR (Alumina Refinery)
Problems identified	Too much waste, Higher Breakdown time, Frequent maintenance
Approach	Process improvement
Kaizen Tools used	Total Productive Maintenance, Basic plan, TPM board,
Results in improvement	OEE improved Breakdown time reduced

### 13. CONCLUSIONS

Following conclusion are made from the study.

1. Kaizen is a continuous improvement tool and it can be applied to all types of industry including process industries. It is never ending process, and continuously improvement should be made in the manufacturing system.
2. For successful implementation of Kaizen, management initiative is required and management role is important. Of course, major improvements are brought by supervisors and workers. Management should act as coach in the process.
3. For getting specific improvement, existing problems should be identifies, and goal based improvement should be made in the kaizen implementation.
4. Selection of critical success factor is required to be focused for successful implementation of kaizen philosophy in the manufacturing organization.
5. Kaizen can work successfully with any type of the problem in the manufacturing organization They may be productivity, quality, consistency, repeatability, machine maintainability, down time, non-value added activities, logistics, waiting time, delay, equipment effectiveness // utilization, operators involvement, etc.

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Success Stories: Kaizen Institute;  
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# Just in Time Manufacturing and Inventory Management: A Critical Literature Review

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**Abstract:** *In the new era of globalization, to meet the ever changing customer demands, manufacturing flexibility, quick delivery time and high productivity along with high profitability, every industry is continuously striving for innovative and effective management techniques. Just In Time (JIT) is the one of such management techniques that increases the profit of the enterprise by elimination of all kind of wastes through continuous improvement. JIT is not just a material management technique but it is an overall philosophy which can be efficiently applied not only in manufacturing sector but also in service sector. JIT provides defect free services or products on right time, right quantity, right quality, right place at lowest possible cost. This paper deals with the introduction, critical literature review and future scope of JIT Based Production System.*

**Keywords:** *Just In Time, Supply Chain Management, Total Quality Management, Material Requirements Planning*

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## 1. INTRODUCTION

Just in time (JIT) is a Japanese production management philosophy. JIT means to produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricate parts just in time to go into subassemblies, and purchase parts just in time to be transferred into fabricated parts. It was firstly developed and perfected within the Toyota manufacturing plants by Taiichi Ohno as a means of meeting consumer demands with minimum delays. In 1954 Japanese Giant Toyota implemented this concept in order to reduce the wasteful overstocking in car production.

According to Voss, JIT is viewed as a “Production methodology which aims to improve overall productivity through elimination of waste and which leads to improved quality”. In the JIT techniques, day-to-day operations are carried out by meeting the demands of customers. Basics of JIT concept are that the company produces only what is needed, when it is needed and in what quantity that is needed. JIT can also be defined as producing the necessary units, with the required quality, in the necessary quantities. It means that company can manage with their own resources and allocate them very easily. JIT also emerged as a means of obtaining the highest levels of usage out of limited resources available.

JIT manufacturing consists of several components or elements which must be integrated together to function in harmony to achieve the JIT goals. These elements essentially include the human resources and the production, purchasing, manufacturing, planning and organizing function of an organization. JIT helps in Effective Material Management by minimizing the degree of time lapse

between material arrivals, processing and assembly of the final product for consumers. The primary goal of JIT is to achieve zero inventory within an organization as well as throughout the entire supply chain. This is achieved by questioning each and every aspect of stock at raw materials stores and in-process buffers etc.

## 2. CRITICAL LITERATURE REVIEW

### 2.1 JIT Exchange Relationships

A new form of exchange relationship commonly referred to as “JIT Exchange Relationship” is being tried to explain. In this paper, it is tried to expand understanding of (i) how JIT exchanges compare with other forms of exchange between suppliers and original equipment manufacturers (OEM) (ii) what conditions are most conducive to the initiation of JIT exchanges, and (iii) what key features are likely to influence the success or failure of initiated JIT exchanges (Frazier et al. 1988).

### 2.2 Rule based approach

In this paper, the example of many of the successful Japanese manufacturing companies is considered and there is a desire in UK to implement many aspects of JIT approach. It is also tried to explain that it is wise to take a step by step approach to the implementation of JIT. A rule based approach to capture and represent the knowledge related to the major elements of JIT production is developed (Pegler et al. 1990).

### 2.3 Key Strategies in JIT Implementation

This paper discusses the various challenges faced in the implementation of JIT for production and procurement strategies. The authors also attempt to identify the key

strategies for successful implementation of JIT production and procurement and emphasize the need for top management commitment so that JIT implementation can take place in an effective manner. It also focuses that the attitudinal adjustments and top management commitment should work in tandem to achieve the benefits of JIT (Bandyopadhyay 1995).

#### **2.4 Management Initiatives Necessary for JIT**

In this paper, a case based research is carried out to find the necessary management initiatives for the implementation of JIT manufacturing. It considers six management initiatives out of which only four are found out to be the necessary management initiatives as necessary conditions for JIT implementation. These four are (i) promotion of employee responsibility (ii) provision of training (iii) promotion of teamwork (iv) demonstration of visible commitment. The others which are rejected are (i) provision of workforce security (ii) use of group performance measures. The results also indicate that employee involvement plays a central role in JIT implementation (Lachlin 1997).

#### **2.5 Integrating Material Requirements Planning (MRP) and JIT**

In this paper, the authors try to provide an overview of the manufacturing planning and control environment associated with Material Requirements Planning (MRP) and JIT. The MRP/JIT comparison that existed is classified and two different perspectives on MRP/JIT are discussed and future research area is proposed based on the taxonomy. The authors have also tried to uncover the potential of MRP/JIT integration that would reduce the MRP nervousness and JIT inflexibility (Benton et al. 1998).

#### **2.6 Relationships between Total Quality management (TQM), JIT and Total Productive Maintenance (TPM)**

In this paper, the authors have tried to investigate the impact and implementation of the three programs namely TQM, JIT and TPM simultaneously. They have also tried to explain that manufacturing performance is associated with the level of implementation of both socially and technically oriented practices of the three programs. This paper also empirically demonstrates the joint implementation of manufacturing programs such as JIT, TQM and TPM (Cua et al. 2001).

#### **2.7 Linkages Between JIT, TQM and Supply Chain Management (SCM)**

This paper empirically examines the extent to which JIT, SCM and TQM are correlated and how they impact business performance. Results demonstrate that at both the strategic and operational levels, linkages exist between how JIT, TQM and SCM are viewed by organizations as a part of their operational strategy. Results also indicate that a

commitment to quality and an understanding of supply chain dynamics have the greatest effect on performance (Kannan et al. 2005).

#### **2.8 JIT Based Work In Process (WIP) Management**

The authors try to explain that WIP is a big problem for manufacturing, especially for many kinds of product manufacturing. Based on the production characteristics and situation of the manufacturing enterprise in China, a task management model is proposed to minimize the WIP. This model is designed to describe and forecast the dynamic interaction and mutual effect between WIP and JIT. The Dispatch List and Electronic Kanban are adopted to realize the JIT control (Li Bo et al. 2007).

#### **2.9 Automated Guided Vehicles (AGV) Systems Based on JIT**

This paper deals with about developing a simulation model of a hypothetical system which has a job shop environment and is based on JIT philosophy. After developing the model, the factors which might be important for the system are determined by the output analysis. A plan is prepared and two levels are selected for each factor and an experimental design is conducted. From the study it is concluded that number of kanban and arrival rate of demand affect the time in system of each job (Kesen et al. 2007).

#### **2.10 JIT Manufacturing Practices and Performance**

In this paper, the author examines the relationship between JIT manufacturing practices and performance outcomes by means of meta-analysis of co-relations approach. Based on an in-depth analysis of literature spanning from 1992 to 2008, the results of this meta-analytic investigation supports a positive relationship between JIT manufacturing practices and aggregate performance. This study highlights the JIT practices that have the greatest impact on individual performance outcomes and emphasized the role of moderating factors in the relationship between JIT practices and performance (Alan et al. 2010).

#### **2.11 JIT Philosophy in Construction Industry**

In this paper the potential impediments to implementing of JIT in the Chinese construction industry and the authors have proposed a framework for the JIT implementation in the areas of design, procurement, construction and inspection. The results of this study suggests that government and educational institutions should play a key role in spearheading the application of JIT in the construction industry in China (Pheng et al. 2011).

#### **2.12 JIT Material Handling (MH) System**

This paper presents a review on the actual implementation of a Gravity Flow Rack (GFR) system at an automotive

components assembly line in an accord its existing material handling system. The main purpose of this paper is to reduce the material transfer activities while reducing the occupied space, hence reducing the overall production cycle time. The implementation outcomes shows significant improvement on the productivity and not to mention the material's handling time (Halim et al. 2012).

### ***2.13 Manufacturing Excellence Through JIT***

The authors propose JIT manufacturing system technique for attaining manufacturing excellence in an industry. Their goal is to increase the capacity and throughput rates, reduce lead time, system for simplification and improve quality and efficiency while reducing operating costs through the implementation of basic JIT tools such as 5S layout, cause and effect diagram, visual controls, rewards and incentive schemes, point of use storage and quality at the source (Kumar et al. 2013).

### ***2.14 Surpassing JIT***

This paper aims to reassess the way management technology was carried out in the manufacturing industry and establish "New JIT, New Management Technology Principle". New JIT consists of the Total Development System (TDS), Total Production System (TPS) and Total Marketing System (TMS) which are the core elements required for establishing new management technology principles. The author proposes a high linkage model, employing a structural "Advanced TDS, TPS and TMS" for expanding "uniform quality world-wide and production at optimum locations (Amasaka 2014).

### ***2.15 Impact of JIT on Organizational Performance***

In this paper, the authors examine the impact of a Total JIT (T-JIT) strategy within a supply chain context and analyzed a model incorporating T-JIT as the focal construct with SCM strategy as an antecedent and Supply Chain Competency (SCC) and organizational performance as consequences. Their results support T-JIT as a viable SCM strategy. The comprehensive strategy of T-JIT will serve to move the supply chain towards the ultimate goal of delivering zero defect, quality products to the ultimate consumers in the exact quantities and at the precise times desired by those customers (Green et al. 2014)

### ***2.16 Benefits of Successful JIT Implementation***

The authors report thirty benefits obtained by companies after a successful JIT implementation. However this research reduces the list by means of a data reduction technique to identify those essential benefits that must be pursued. A factor analysis is done and four main factors related to the JIT benefits were identified. Identified factors concern inventory management, production process, human resources and economic benefits (Alcaraz et al. 2016).

### ***2.17 Internet of Things (IOT) Based Solutions***

This paper presents a research on using IOT based solutions to enhance JIT manufacturing. The general challenges of JIT implementation are identified and then an IOT based solution is proposed to address the JIT challenges in a selected case study. A framework to support the proposed IOT solution is developed and its implementation steps are suggested (Yuchun et al. 2016).

### ***2.18 Ranking of Performance Indicators using DBA***

This paper deals with the identification and ranking of the performance indicators based on various criterion for successful implementation of JIT in manufacturing sector. A deterministic quantitative model based on Distance based approximation (DBA) technique has been developed for identifying and ranking the performance indicators namely-Lead Time Reduction, Productivity, Profit, Product Quality, Difficulty in Implementation and Inventory . The major outcome of the work is the identification of JIT criterion for selection of performance indicators. This work facilitates selection of right JIT elements for a specific performance indicator of supply chain which is one of the major problems in JIT context (Ranjan et al. 2016).

### ***2.19 Decision Making Delays in MRP and JIT***

This paper considers the relations between the production control systems (MRP and JIT) and the organization structure of information processing that determines the decision making delay. They compared MRP and JIT across different information processing structures and decision efficiency, and find that JIT is suitable for small lot size and large variety production and MRP for large lot size and small variety production (Wang et al. 2017).

### ***2.20 Ranking of Performance Indicators using SAW***

This paper mainly includes the ranking of performance indicators on the basis of various criterion for successful implementation of JIT in various industries. Simple Additive Weighting (SAW) technique is used for making a deterministic quantitative model for identification and ranking of performance indicators. In this paper six performance indicators are mainly used. If selection of these performance indicators is not taken properly, it would affect the productivity of companies adversely. The main finding of this work is identifying JIT criterion for selection of performance indicators (Kamboj et al. 2017).

## **3. CONCLUDING REMARKS AND FUTURE SCOPE**

This Critical Review reveals that combined management techniques are more effective rather than benefits obtained using a single technique i.e. we should go for collaborative approach. Just In Time (JIT), Total Quality Management (TQM), and Total Productive Maintenance (TPM) together

affect manufacturing programs both socially and technically. JIT exceeds the concept of inventory reduction. It is an all-encompassing philosophy geared to eliminate waste, anything that does not add value. Firstly an industry should implement “most important and least difficult to implement” JIT elements. It consists of several components or elements which must be integrated together to function in harmony to achieve the JIT goals. These elements essentially include the human resources and the production, purchasing, manufacturing, planning and organizing function of an Organization. JIT is not just a material management technique but is an overall philosophy which can be efficiently applied not only in manufacturing sector but also in service sector. JIT helps in Effective Material Management by minimizing the degree of time lapse between material arrivals, processing and assembly of the final product for consumers.

The present work on JIT is exploratory in nature. The concept of JIT presently has been applied in the manufacturing sectors and can be further extended to the service sectors such as banking, healthcare and hospitality etc. Using JIT methods to concentrate on decreasing the time required to provide a service, improving the quality of the service and essentially increasing the productivity of the organization are all potential advantages that may result from further research and application of JIT techniques in service oriented organizations.

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# A Study of Association of Lean Manufacturing Implementation and Safety in a Pump Manufacturing Company: A Case Study

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**Abstract:** Lean Manufacturing (LM) is a popular technique of production management. It is an improved version of Just-in-Time which was evolved 1950s in Japan. Since evolution of Lean Manufacturing there have been many studies highlighting various aspects of Lean Manufacturing. The present research project was undertaken with objective of assessing impact of LM implementation on safety. It was observed that implementation of LM has led to increase in PPE availability and usage. The safety level of the organization has also gone up since LM implementation.

**Keywords:** Lean Manufacturing, Safety practices, Safety Level

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## 1. INTRODUCTION

Lean manufacturing has become very popular tool for production management lately. Industries from various domains are adopting LM in hope of improving their performances. Many researchers have studied LM's implementation in different industries in different countries all over the world. The purpose of this research study is to identify various factors which affect Lean Manufacturing Implementation in pump manufacturing industry. Lean Manufacturing (LM) refers to a business concept wherein the goal is to minimize the amount of time and resources used in the manufacturing processes other activities of an enterprise; its emphasis is on eliminating all forms of wastage.

## 2. LITERATURE REVIEW

Since the development of LM there have been numerous studies and researches on various aspects of LM. Here is a brief overview of previous works:

Priti B. Khadse(2013) et al. have presented purpose of this research is to first identify the critical lean manufacturing factors responsible for implementation of lean manufacturing in the Indian manufacturing sector and then to incorporate these factors into a framework, which can be represent the present status of lean practices in Indian industries.

Alireza Anvari (2011) et al-have discussed the relationship between Lean Manufacturing environments and Safety Management Systems. The creation of a Lean environment in a workplace requires employee motivation and good management. All the different levels of an organization need to put forth their best efforts on a day-to-day basis and

work together toward achieving improved performance and reducing waste. 5S (Sort, Set in order, Sweep, Standardize, Sustain) is one of the most effective tools of Lean manufacturing because it is the basis for an effective Lean implementation.

Gurumurthy (2008) et al. made an attempt to demonstrate the application of a Multi Attribute Decision Making model, namely Performance Value Analysis (PVA) to analyze the alternatives production system like Traditional manufacturing, Computer Integrated Manufacturing, and Lean Manufacturing among various performance measures.

Abdulmalek et al. (2007) described a case where lean principles were adapted for the process sector for application at a large integrated steel mill. Value Stream Mapping was the main tool used to identify the opportunities for various lean techniques.

## 3. PROBLEM FORMULATION & OBJECTIVES

The purpose of this research is to firstly identify the critical lean and safety factors manufacturing factors responsible for implementation of lean and safety manufacturing in the Indian manufacturing sector and then to incorporate these factors into a framework.

### 3.1 OBJECTIVES OF THE STUDY

The primary objective of this study is to study the impact of Lean manufacturing implementation on the safety standard in the company. The objectives of this research are:

- 1) To determine change of safety level post LM implementation.

- 2) To determine any change in use of PPEs after LM implementation

#### 4. RESEARCH METHODOLOGY

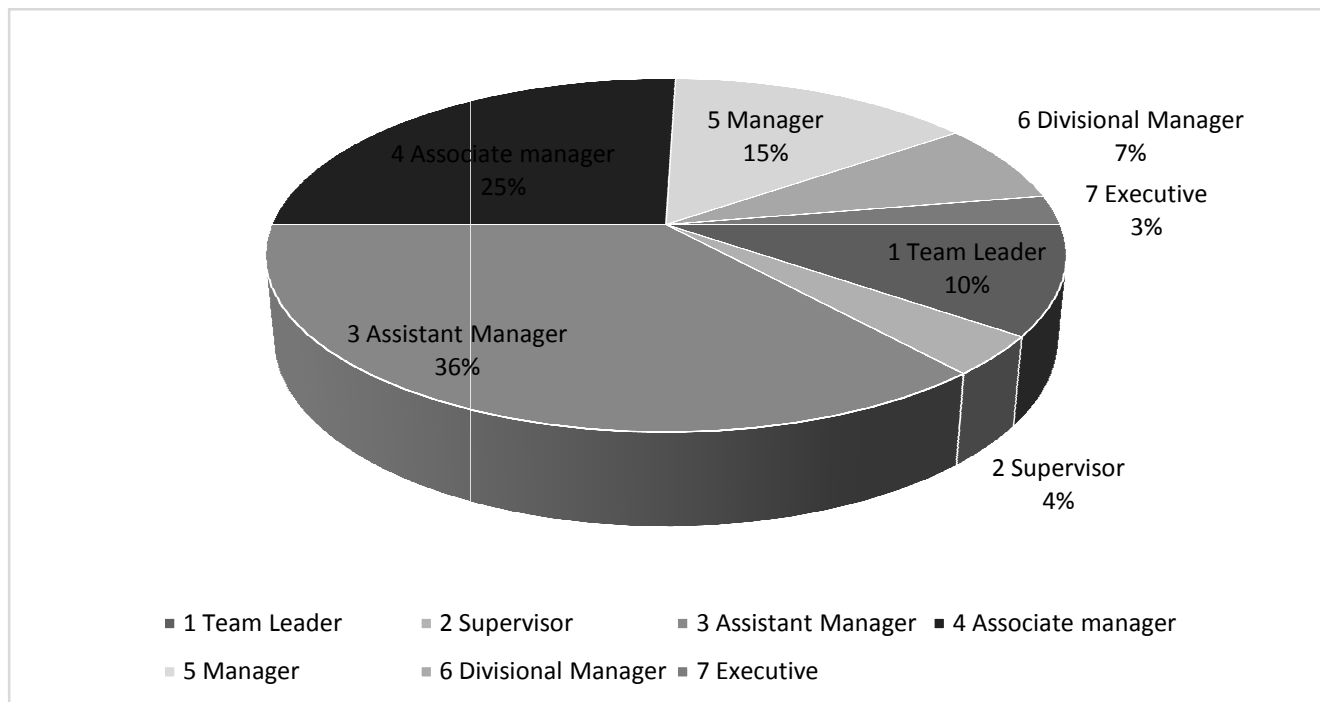
A structured questionnaire was prepared and distributed amongst the staff members of pump manufacturing organizations. The responses so collected were then subjected to statistical analysis using MS Excel and SPSS software.

#### 5. DATA ANALYSIS AND RESULTS

A total of 130 questionnaires were distributed amongst the employees and 113 responses were received. Out of the 113 responses 4 were found incomplete and hence 109 responses were found to be valid. The response rate was 83.84% Respondents from different post and job titles were included in the survey. A detailed review of respondents' job titles and frequency is given below:

**TABLE 1 Classification of respondents based on Job Title**

S. No.	Job Title	No. of responses
1	Team Leader	10
2	Supervisor	4
3	Assistant Manager	40
4	Associate manager	28
5	Manager	16
6	Divisional Manager	8
7	Executive	3
Total		109



**Fig. 1 Respondents' Job Title Profile**

##### 5.1 Responses available

The responses were collected by distributing questionnaire amongst the employees and collecting them after an appropriate time interval.

**TABLE 2: Responses Availability Statistics**

Group No.	Departments included	Plant 1 Plant
1	Ind. Engg. +Mfg. +Production +product development Management + Industry segment	28
2	Assembly Section	16
3	QA+ Maintenance	23
4	Supply Chain +Vendor + Procurement +stores+ spares & services	24
5	HR+ Finance +Others	18
	Total	109

## 5.2 Testing of Data

### 5.2.1 Internal Consistency Analysis

Internal consistency is one of the methods that can be used for assessing reliability (Nunnally, 1978). It checks whether the gathered data is reliable enough or not. There are various measure to check consistency of the data. In this research Cronbach's Alpha was used. Cronbach's alpha ( $\alpha$ ) or Coefficient alpha is a measure of internal consistency reliability that is the average of all possible split-half coefficients resulting from different splitting of the scale terms [Malhotra and Dash, 2011]. Table 4 gives the value of Cronbach's alpha for various parameters.

**TABLE 3: Cronbach's Alpha for variables**

S. No.	Item	No. of Items	Cronbach's Alpha
1	Implementation of Lean Manufacturing	6	0.783
2	Level of Safety	11	0.877
3	Use of PPE	5	0.790
Overall		22	0.834

## 5.3 Analysis of Data

Once the reliability of data is assured it can be subjected to further analysis. In this research the data was subjected to Correlations analysis and Hypothesis testing.

### 5.3.1 Correlations Analysis

Correlation analysis is used to identify existing relationships between variables. The analysis tells if there exists any effect of one variable on the other. To calculate it, Pearson's Coefficient is the most common measure of measuring correlations. Also while assessing the strength of relationship, significance or p value is important. For a confidence level of 95%, the significance value must be lower than 0.05 in case of one tailed test and less than 0.025 in case of two tailed test.

**TABLE 4: Correlation between availability of PPE and its usage**

		PPE_ Availability	PPE Usage
PPE Availability	Pearson Correlation	1	
	Sig. (1-tailed)		
	N	109	
PPE Usage	Pearson Correlation	<b>.920 **</b>	1
	Sig. (1-tailed)	.000	
	N	109	109

The Pearson's correlation coefficient between PPE availability and PPE usage was found to be 0.920 suggesting that they have a strong positive correlation.

**TABLE 5: Correlation between LM implementation and No. of accidents**

		LM Extent	No. of Accidents
LM Extent	Pearson Correlation	1	
	Sig. (1-tailed)		
	N	109	
No. of Accidents	Pearson Correlation	<b>-0.669 **</b>	1
	Sig. (1-tailed)	.000	
	N	109	109

****significant at 0.01**

A strongly negative correlation coefficient between 'LM extent' i.e., extent of LM implementation and No. of near miss suggests that implementation of LM leads to decrease in no. of near miss incidents.

**TABLE 6: Correlation between LM implementation and No. of Near Miss**

		LM Extent	No. of Near miss
LM Extent	Pearson Correlation	1	
	Sig. (1-tailed)		
	N	109	
No. of Near miss	Pearson Correlation	<b>-0.753 **</b>	1
	Sig. (1-tailed)	.000	
	N	109	109
**significant at 0.01			

### 5.3.2 Hypothesis Testing

*t* test is a univariate hypothesis test using the *t* distribution, which is used when the standard deviation is unknown and the sample size is small. One sample *t* test is used here to check the validity of hypotheses. The hypotheses were tested at the mean value of 4.

#### Hypothesis 1:

H01: There is no significant change in the extent of use of PPEs before and after LM implementation

H11: There is a significant change in the extent of use of PPEs before and after LM implementation

**TABLE 7: One sample *t* test for 'Use of PPE'**

	Test Value = 4					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
PPE usage	2.300	108	.023	.148	.02	.28

#### Hypothesis 2:

H02: There is no significant change in the overall level of safety on the shop floor post LM implementation

H12: There is a significant change in the overall level of safety on the shop floor post LM implementation

**TABLE 8: One sample *t* test for Safety Level**

	Test Value = 4					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Safety Level	2.614	108	.017	.253	.03	.26

As stated above, the hypotheses were tested using one sample *t* test. The test was applied at a mean level of 4 with significance level of 0.05. From the results shown in table 7 and 8 it is found that both the null hypotheses were rejected which implies that there has been a change in use of PPEs in the plant as well as the safety level was improved post LM implementation.

## 6. CONCLUSION

The research was undertaken with objectives of assessing the change in safety level and practices in the organization post LM implementation. It was observed that LM implementation has a positive impact on the safety standard in the company. The respondents from all the departments have the perception that implementation of LM has led to reduction of near miss as well as accidents in the plants. This can be attributed to the increased availability and usage of PPEs and improved awareness of safety measures amongst the worker. No significant change has been registered in the safety training of the workers. The training policy of the organization has remained unaffected by LM implementation.

## 7. FUTURE SCOPE

The study can be extended further to other manufacturing organizations so as to gather more empirical evidence on the topic. A study may be conducted on those organizations which have not yet implemented the LM but are planning to do so. Such a research will be more comprehensive and is likely to provide better insights.

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# Implementation of Integrated FMEA and TPM to SME: A Case Study

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**Abstract:** Despite their high enthusiasm and inherent capabilities to grow, SMEs in India are facing a number of problems like technological obsolescence, increasing domestic and global competition, and change in manufacturing strategies. To survive with such issues and compete with large and global enterprises, SMEs need to adopt innovative approaches in their operations. Failure Mode and Effects Analysis (FMEA) is one of the most effective techniques to achieve high reliability and Total Productive Maintenance (TPM) improves product quality, reduce waste, reduce manufacturing cost, increase equipment availability. This paper provides guidelines for SMEs to implement FMEA-TPM for improving Reliability and quality of production process by briefing case study of SME.

**Keywords:** Reliability, Quality, FMEA, Faults classification, TPM Pillars.

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## 1. INTRODUCTION

Micro, small and Medium Enterprises (MSMEs) are one of the most vibrant and sensitive sectors in Indian economy. The significance of Micro, small and Medium Enterprises (MSMEs) is attributable to its capacity of employment generation, low capital and technology requirement, use of traditional or inherited skill, use of local resources, mobilization of resources and exportability of products. Despite their high enthusiasm and inherent capabilities to grow, SMEs in India are also facing a number of problems like technological obsolescence, increasing domestic and global competition, and change in manufacturing strategies. With the introduction of reform measures in India since 1991, the Govt. has withdrawn many protective policies for the Micro, Small and Medium Enterprise (MSMEs) and introduced promotional policies to increase competitiveness of the sector. To survive with such issues and compete with large and global enterprises, SMEs need to adopt innovative approaches in their operations (Annual Report *et al.*, 2012-13 Govt. of India). Failure modes and effects analysis (FMEA) is one potential tool used in reliability engineering. FMEA is a reliability procedure which documents all possible failures in a system design within specified ground rules. It determines, by failure mode analysis, the effect of each failure on system operation. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones (George Pantazopoulos *et al.*, 2005).

Total Productive Maintenance (TPM) is a unique Japanese philosophy, which has been developed based on the productive maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd.

of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971 (Nakajima *et al.*, 1988). TPM is a waste reducing approach to stabilise utilisation of machining resources. TPM focuses on improving machine availability and includes monitoring of machine equipment called overall equipment efficiency to visualise losses of utilisation. Implementation of TPM usually starts with a pilot project (Jostes *et al.*, 1994). The main focus of TPM is on the condition of the equipment and its influence on quality of output. Eight pillars of TPM are 5s, autonomous maintenance, continuous improvement (kaizen), planned maintenance, quality maintenance, education and training, office tpm, safety, health and environment control.

## 2. LITERATURE REVIEW

Karaulova *et al.* (2012) used Faults classification for machinery enterprises developed the reliability assessment. The system identified the most unreliable parts of a production process and suggests the most efficient ways for the reliability improvement. Rajesh Bajaj *et al.* (2011) carried out efforts towards identifying the specific TPM activities, which can be implemented for a particular type of enterprise and achieve the benefits; without investing the resources. For large enterprises allocation of all these resources may not be a difficult. However for a medium or small or micro enterprise, which are always under constraint due to resource paucity, application of Total Productive Maintenance in totality may not be feasible. Next best alternative he suggested is to identify pillar wise activities, which can be undertaken by the medium, small or micro enterprises to achieve the benefits from TPM.

Waghmare et al. (2015) proposed an integrated approach of FMEA-TPM by using fault classification and tpm pillars for improving reliability and quality of SMEs. The faults are classified under seven classes of failures. The preferences for attending classes of faults and for implementing TPM pillars are suggested.

- Preference for attending fault classes- 1st Training Deficiency (TD), 2nd Management Problem (MP), 3rd Equipment Problem (EP), 4th Design Problem (DP), 5th Procedure Problem (PP), 6th External Phenomena (EXP), 7th Personal Error (PE)

The above preferences fault classes can be used to improve reliability of production process.

- Preference for implementing TPM pillars –1st Educating and Training (ET), 2nd Kaizen (KAI), 3rd Safety-Health-Environment (SHE), 4th Autonomous Maintenance (AM), 5th Quality Maintenance (QM), 6th Seiri, Seiton, Seiso, Seiketsu, Shitsuk (5S), 7th Planned Maintenance (PM)

### 3. METHODOLOGY

#### 3.1 Case Study Problem

Company A was started in 1990 with a manufacturing set up to produce quality press tools, dies and fixtures heat

treated aluminium and aluminium alloy forging. Company A was having marginally high rate of rejection of CNG Distributor Block. Figure 1 shows CNG Distributor Block.



**Fig. 1. CNG Distributor Block**

The rejection data for four months were collected. The data was collected for four months because the rejection rate was not uniform and in order to get overview of rejection. The average rejection of screws was 0.864% found. The details of rejection were shown in table 1 which consists of Inspected Quantity, Rejected Quantity and % age of rejection. The data collected for five months, those were April-15, May-15, June-15 and July-15.

**TABLE 1: Details of rejection CNG Distributor Block**

<i>Months</i>	<i>Total Production</i>	<i>Total Accepted</i>	<i>Total Rejection</i>	<i>% of Rejection</i>	<i>Average % of Rejection</i>
Apr-15	14257	14134	123	0.862734	0.85635
May-15	22850	22636	214	0.936543	
Jun-15	13667	13555	112	0.819492	
Jul-15	16075	15946	129	0.802488	

The details of defects for CNG Distributor Block were shown in table 2.

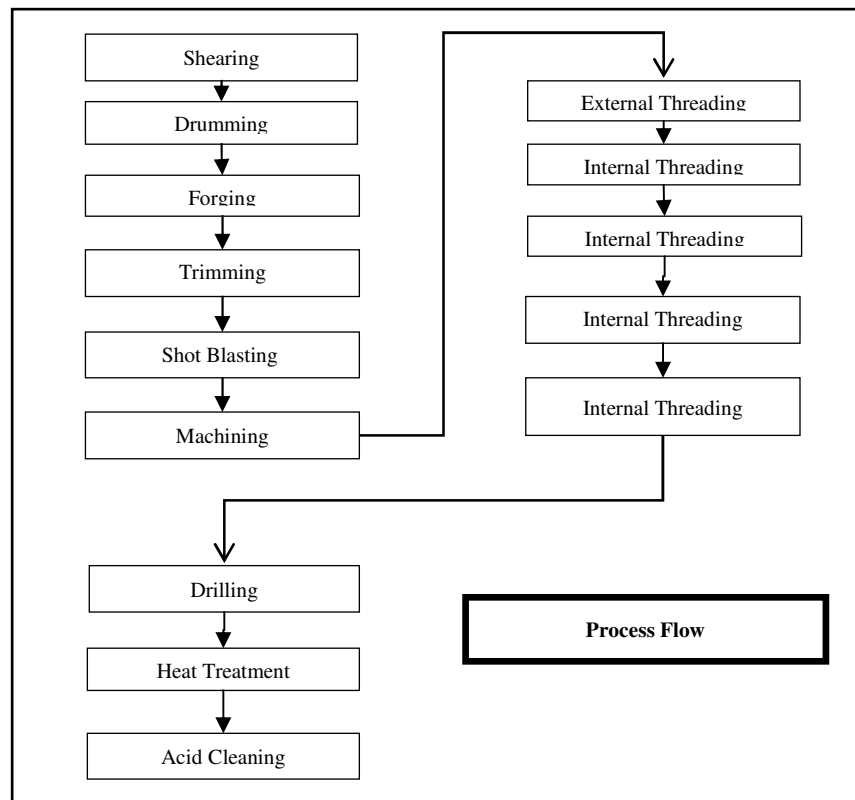
**TABLE 2: Details of defects for CNG Distributor Block**

<i>Month</i>	<i>Under filling</i>	<i>Surface cracking</i>	<i>Fold mark</i>	<i>Pitting</i>	<i>Foreign body</i>	<i>Shop scrap</i>	<i>Mismatch</i>	<i>Improper grain flow:</i>	<i>Total rejection</i>
Jan-15	31	11	13	21	14	9	16	8	123
Feb-15	52	19	24	37	25	21	23	13	214
Mar-15	25	13	10	16	14	11	14	9	112
Apr-15	33	10	15	19	17	12	12	11	129



### 3.2 Processes in CNG Distributor Block Manufacturing

The flow chart for processes in CNG Distributor Block manufacturing is shown as follows in Figure 2.



**Fig. 2. Processes in CNG Distributor Block manufacturing**

### 3.3 Causes and Remedies for Defects of CNG Distributor Block.

After studying the CNG Distributor Block manufacturing processes defects are studied and the causes and remedies are suggested which is shown in following table 3.

**TABLE 3: Defects, causes and remedies for CNG Distributor Block**

Sr.No.	Defect	Cause	Remedy
1	Underfilling	Excess use of diecoat	Training to operator
		Less weight of billet	check feeder mechanism to shearing machine
		Improper use of method	Training to operator, Strictly use of work instruction provided
		Operator new	Training to operator
		Low billet temperature	Proper furnace temperature setting
		Temperature	Modify burner position and calibrate furnace for temperature.
		Die deformation Grinding of blocker die as per template.	Grinding of blocker die as per template.
		Die design	Modify blocker die design by mapping unfilled zone.
		Lubricant	Select the best lubricant for die.

Sr.No.	Defect	Cause	Remedy
		Improper design of the forging die or using forging techniques, less raw material, poor heating.	Strictly use of work instruction provided
2	Surface cracking	Excessive working on the surface and too low temperature.	To increase the work temperature
		Material defect	Check for composition of material as per requirement
3	Fold mark Two surfaces of metal fold against each other without welding completely.	Sharp corner (less fillet), excessive chilling, high friction	Increase fillet radius on the die.
		Shearing operation is not proper	Check for sharpness of shearing die
4	Pitting	Scales	Remove scales in blocker forging or finisher forging through preventive maintenance of descale.
5	Foreign body	Unwanted material	Remove foreign body from sawdust through checking of sawdust while mixing with water.
		Chips	Air should be blown properly before placing hot billet both in blocker and finisher die.
6	Shop scrap	Temperature	First zone temperature to keep higher side for better soaking.
		Delay	Preventive maintenance of conveyors and manipulators for smooth movement of billet from furnace to die.
7	Mismatch (Die shift) Misalignment of forging at flash line.	Misalignment of the die halves.	Proper alignment of die halves. Make mistake proofing for proper alignment for eg. Provide half notch on upper and lower die so that at the time of alignment notch will match each other, Use of guide pins for die.
8	Improper grain flow:	Improper die design, which makes the metal not flowing in final interred direction.	Improper die design.

The defects are grouped as per classes of failures as shown in following table 4.

**TABLE 4: Classes of failures for defects for CNG Distributor Block**

Sr. No.	Class of Failure	Defect
1	Design problem	Less weight of billet, Low billet temperature, Die design, Improper design of the forging die or using forging techniques, Sharp corner (less fillet), Improper die design, which makes the metal not flowing in final interred direction
2	Equipment problem	Die deformation Grinding of blocker die as per template, Poor heating, Misalignment of the die halves.
3	Management problem	Scales, Delay
4	Personal error	Excess use of die coat, Shearing operation is not correct
5	Procedure	Improper use of method, Low temperature, Lubricant, Excessive working on the surface and

Sr. No.	Class of Failure	Defect
	problem	too low temperature, Excessive chilling, high friction
6	Training deficiency	Operator new, Unwanted material, Chips
7	External phenomena	Less raw material, Material defect

Design problems are created due to inadequate designs, drawing specification, or data error, dimensions related problems, and technological parameters problems. Equipment problems are created due to Defective or failed part, equipment failures, bad equipment works, contaminations, critical human errors. Management problem are created due to Inadequate administrative controls, work organisations or planning deficiency, inadequate supervisors, improper resource allocations, policy not adequately defined or enforced. Personnel errors are created due to in adequate work environments, in attention to detail, violation of requirement or procedure, verbal communication problems. Procedure problem are created due to defective or inadequate, lack of procedure, error in equipment or material selection, error in tool or cutting data selection. Training deficiency are created due to no training provided, insufficient practice or hands-on experience, in adequate content, insufficient refresher training on or materials, inadequate presentations or materials. Management problems are created due to inadequate administrative controls, work organisations or planning deficiency, inadequate supervisors, improper resource allocations, policy not adequately defined or enforced.

### **3.4 Implementing FMEA-TPM approach for CNG Distributor Block.**

Steps for implementing FMEA-TPM approach for CNG Distributor Block as given below.

1. Introduction to approach.
  2. Discussion with staff and motivating them to use their experience for reducing defect.
  3. Arranging training to the staff members.
  4. Implementation of the FMEA-TPM.
  5. Measurement of failures after implementing the approach.
  6. Comparisons for improvement if any otherwise repeat the procedure.
- Preference for attending fault classes-  
1st Training Deficiency (TD), 2nd Management Problem (MP), 3rd Equipment Problem (EP), 4th

Design Problem (DP), 5th Procedure Problem (PP), 6th External Phenomena (EXP), 7th Personal Error (PE)

The above preferences fault classes can be used to improve reliability of production process.

- Preference for implementing TPM pillars –  
1st Educating and Training (ET), 2nd Kaizen (KAI), 3rd Safety-Health-Environment (SHE),  
4th Autonomous Maintenance (AM), 5th Quality Maintenance (QM), 6th Seiri, Seiton, Seiso, Seiketsu, Shitsuk(5S), 7th Planned Maintenance (PM)

After discussion done with company people they decided to give preference 1st Training Deficiency (TD), 3rd Equipment Problem (EP) regarding classes of failures and regarding implementing TPM pillars they decided to give preference 1st Educating and Training (ET), 2nd Autonomous Maintenance (AM)

Training deficiency are created due to no training provided, insufficient practice or hands-on experience, in adequate content, insufficient refresher training on or materials, inadequate presentations or materials. Equipment problems are created due to Defective or failed part, equipment failures, bad equipment works, contaminations, critical human errors.

Autonomous maintenance: -

- Fostering operator ownership
- Perform cleaning
- Lubricating
- Tightening
- Adjustment
- Inspection
- Readjustment on production equipment.

Educating and Training: -

- Imparting technological Quality control and Interpersonal skills
- Multi-skilling of employees

- Aligning employees to organizational goals
- Periodic skill evaluation and updating

The above two pillars of TPM were implemented. Autonomous maintenance training was given to the operators with the help of maintenance department people.

The training programmes were arranged by arranging experts within the company so that workers they will get motivated. The incentive schemes were declared for zero defects and zero maintenance work. After implementing FMEA-TPM approach the rejection data collected for four months shown in table 5.

**TABLE 5: Details of rejection after FMEA-TPM for CNG Distributor Block**

<i>Month</i>	<i>Quantity received</i>	<i>Quantity accepted</i>	<i>Quantity rejected</i>	<i>% of rejection</i>	<i>Average % of Rejection</i>
Sep-15	13883	13819	64	0.460995	0.454252
Oct-15	21742	21623	119	0.547328	
Nov-15	14142	14084	58	0.410126	
Dec-15	15971	15908	63	0.394465	

### 3.5 Details of Defects after FMEA-TPM Approach for CNG Distributor Block.

The details of defects were shown in table after FMEA-TPM approach shown in table 6.

**TABLE 6: Details of defects after FMEA-TPM approach for CNG Distributor Block**

<i>Month</i>	<i>Under filling</i>	<i>Surface cracking</i>	<i>Fold mark</i>	<i>Pitting</i>	<i>Foreign body</i>	<i>Shop scrap</i>	<i>Mismatch</i>	<i>Improper grain flow:</i>	<i>Total rejection</i>
Sep-15	16	6	7	11	8	4	9	3	64
Oct-15	31	11	13	19	14	9	15	7	119
Nov-15	13	7	6	7	8	6	5	6	58
Dec-15	19	4	8	10	7	3	5	7	63

## 4. CONCLUSION

In this company the classes of failures attended were 1st Training Deficiency (TD), 2nd Equipment Problem (EP) and to overcome these classes of failures, they decided to implement 1st Educating and Training (ET), 2nd Autonomous Maintenance (AM). The above two pillars of TPM were implemented. Autonomous maintenance training was given to the operators with the help of maintenance department people. The training programmes were arranged by arranging experts within the company so that workers they will get motivated. In autonomous maintenance covered Fostering operator ownership; perform cleaning, lubricating, tightening, adjustment, inspection, readjustment on production equipment. In educating and training covered imparting technological quality control and interpersonal skills, multi-skilling of employees, aligning employees to organizational goals, periodic skill evaluation and updating. The incentive schemes were declared for zero defects and zero maintenance work. It is found that before implementing FMEA-TPM approach the average rejection of CNG Distributor Block for four months was 0.85635%

and after implementing FMEA-TPM approach the average CNG Distributor Block rejection for four months was reduced to 0.454252%. The FMEA-TPM approach reduced rejection of CNG Distributor Block by 45.52%, which was reasonably good.

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# Application of SMED Methodology: A Case Study in Small Scale Industry

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**Abstract:** Perfection is not attainable. But if we chase perfection, we can catch Excellence. To stand up in today's Globalization world, Manufacturers need to find ways to reduce Production time and cost in order to improve operating performance and Product quality. It is normally possible to greatly reduce the setup times. Fantastic results are possible through better teamwork, good order, Planning and simple modifications. The main objective of this paper to reduce cycle time of a operation by using Single Minute Exchange of Dies (SMED). This Study is carried out in one of the automotive industry. The SMED system proved a track record in many types of industries. The results Shows that the this study has achieved more than 30% of Cost reduction, 97sec can be reduced which increases the productivity. Single Minute Exchange of Dies (SMED) is the approach to increase output and reduce quality losses

**Keywords:** SMED, Cycle Time, Internal and External Activity, bottleneck

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## 1. INTRODUCTION

In today's global economy consumer are demanding quicker turnaround times along with a larger variety of quality products and specific features. Being able to predict variations in customer demands makes forecasting a complex process. As trends change so do consumer demands for different specifications sizes, colors, styles, and accessories for the products.

A set-up will normally consist of a number of separate tasks, some of which can only be carried out when the machine or process is stopped and some of which could be carried out when the machine or process is running. Shingo called these 'internal' and 'external' to describe the process. However, when applying the technique in your own factory you should consider choosing terms, which are more meaningful in your particular environment. Some possibilities are:

1. In Process (IP) and Not In Process (NIP)
2. Run Time Activities (RTA) and Stop Time Activities (STA)
3. Critical Change-Time (CCT) and Non-Critical Change-Time (NCT)

### Examples of 'internal' activities are:

- Removing work from the machine
- Removing tools dies etc.
- Cleaning down the work surfaces
- Fixing new tools in place
- Fixing the new work piece in place

- Trial run and adjusting the machine

### Examples of 'external' activities are:

- Getting instructions for the next job
- Getting material for the next job from stores
- Getting tools for the next job from tool stores
- Returning tools from the last job to tool stores
- Arranging for lifting equipment to be available when required [1]

Arranging for a setter to be available when required There are a number of potential advantages to reducing the time taken to changeover a production line. These include:

1. Increased efficiency.
2. Reduced stock requirement.
3. Increased capacity.
4. Reduced work in progress.
5. Increased flexibility.

### Four steps to SMED

Discriminate operations that MUST be done while machine is stopped, called internal setup (IS), from those possibly done while machine runs, called external setup (ES), and useless operations.

1. Suppress useless operations, convert IS operations into ES
2. Simplify fittings and tightening
3. Work together!
4. Suppress adjustments and trials Internal setup tasks reduction.[6]

### Preparations of Prerequisites:

- i) Tools, parts
- ii) Instructions
- iii) Lifting material
- iv) Pre-assemblies
- v) Presets
- vi) Pre heating
- vii Unify parts storage, boxes, crates

### Simplify fittings and tightening:

suppress them partially or even totally minimize " turning " movements: they request several grasp-release motions! fit at once, in a single motion use blocks, jigs, templates standardize tools, types and size of screws, nuts...[3]

### Adjustments:

fix standard values  
find out adjustment-less methods through physical means, like stoppers, blocks...  
Get custom made tools if necessary

### Work together:

Setup a racing pit team

### Trials:

make it good at once

## 2. METHODOLOGY

**The SMED system can be summed up as;**

### (a) Measure

Measure the current changeover times and record them in order to monitor improvement (Often simply measuring the changeover time can improve things.)

### (b) Separate “External” and “Internal” activities

“External” activities are simply the jobs that can be carried out while the machine is running (e.g. fetching new tooling and tools required for changeover). “Internal” activities are those jobs which cannot be carried out while the line is running (e.g. changing moulds). By separating the two activities it is intended that as much as possible is carried while the line is running in preparation of the next product changeover.

### (c) Convert “Internal” to “External” activities

The next step is to try and convert some of the internal tasks into external tasks; this might mean having extra tooling to allow equipment to be prepared prior to the line stopping.[4]

### (d) Reduce the time to carry out internal tasks

Of the tasks remaining that cannot be converted to external tasks then efforts should be made to reduce the time taken to carry out these tasks often these require design changes and engineering. Shingo puts forward lots of ideas (such as quick release fastenings, keyhole slots and setting jigs and using a single head size on bolts) in his book to enable this to happen.

### Collection of data:

- Actual changeover duration,
- Describe actual method, equipment, tools,
- Take video shots and analyze motions
- Stopwatch every step, every operation,
- Count the steps, measure walking distances

With such investigations, you can bet on reluctance of non-involved staff!

Probably analyzing data will show the need for 5S action, in order to make tools and equipment handy, as well as a new workshop layout to avoid or minimize useless motions.

If changeover isn't standardized in a formal document, creation of procedure or operation manual will avoid mistakes, needs for some controls or post operation trimmings.[5]

## 3. CASE STUDY OF SHAM METAL WORKS PVT.LTD

### Problem Statement:-

On Machine: CNC 01 in Change over Process:Yoke Shaft & Mid Ship Shaft Turning 38 Min required due to this Machine Is Our Bottel Neck and it takes a lots of effect on our availability for production.

## AVAILABILITY & PRODUCTION LOSS DETAILS

**TABLE 1: Availability & Productivity Loss**

Sr. no.	Part name	Daily change over	Availabiliy Loss (Min)	Production loss (in a day)	Part in month
01.	Yoke shaft	01	38	03	75
02.	Mid ship shaft	01	38	07	175

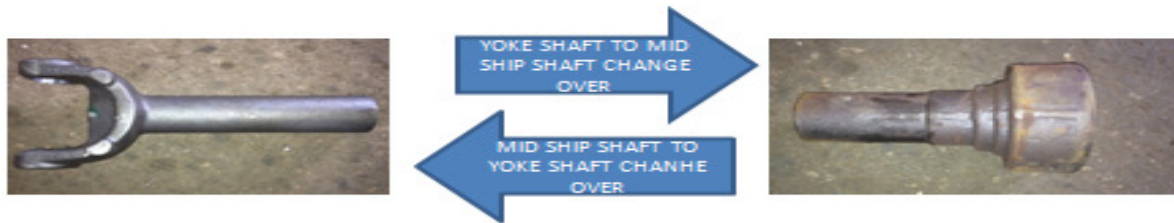


Fig. 1. Parts change over

Analysis of Operation:-

TABLE 2: Analysis of Operation

SR NO.	ACTIVITY.	TIME (Min)
01.	Center collect	01
02.	Allen key set collect	01
03.	Back plate open with setting(M12 Allen bolt 06 nos)	08
04.	Center holder open(M8 Allen bolt 04 nos)	04
05.	Stopper plate open (04 plate M6 Allen 02nos per plate)	06
06.	Center change	01
07.	Back plate mount	05
08.	Stopper plate mount	04
09.	Center holder mount	04
10.	Center inset	0.5
11.	Tail stock declamp/clamp	01
12.	Tail stock center set (M5 06 Allen bolt & 01sensor)	2.5
	TOTAL	38 min

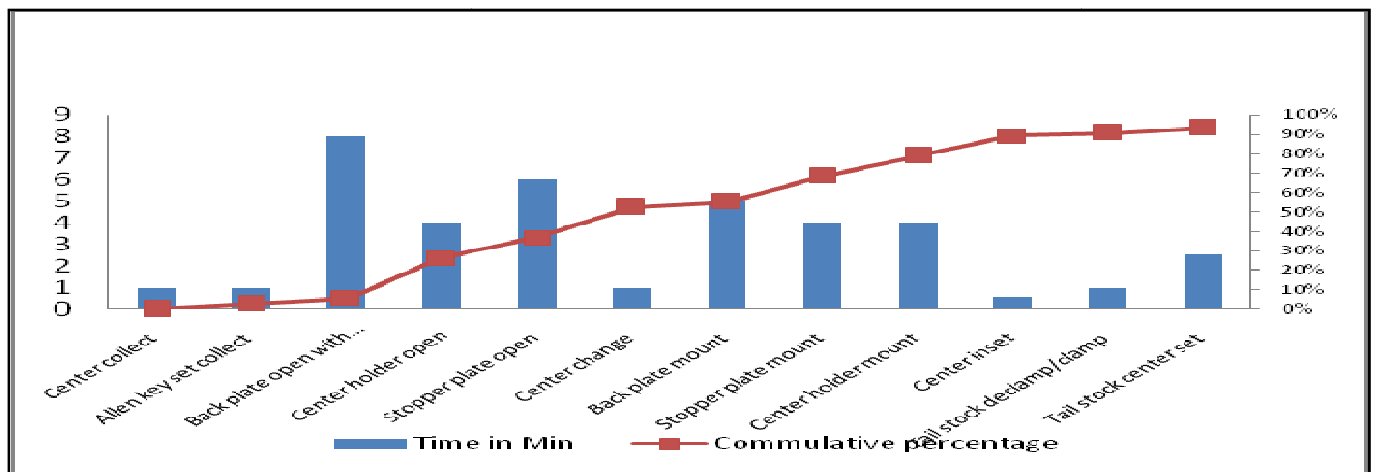
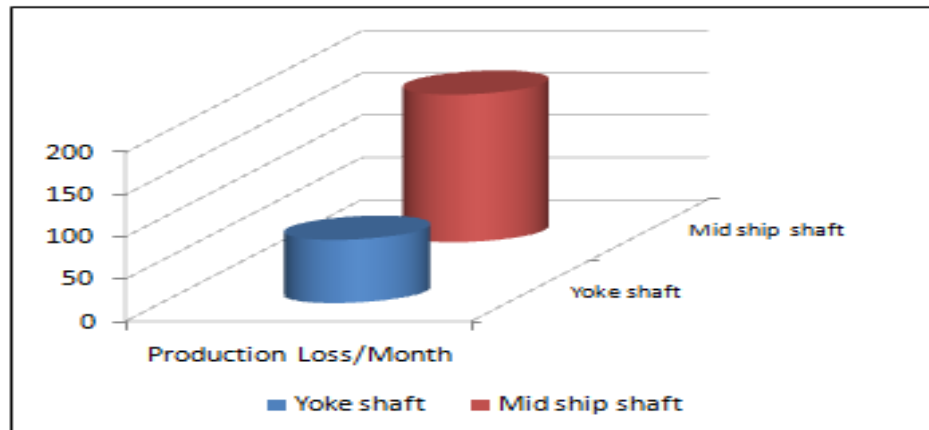


Fig. 2. Pareto Analysis Of A Operations



Pareto through which we can identify the steps where NVA added activities happen we target them and achieve the production capacity as per requirement.



#### ACTIVITY FOR CHANGE OVER(BEFORE):

TABLE 3: Identification of Internal & External in Phase 1

SR NO.	ACTIVITY.	TIME (Min)	ACTIVITY TYPE.
01.	Center collect	01	External
02.	Allen key set collect	01	External
03.	Back plate open with setting(M12 Allen bolt 06 nos)	08	External
04	Center holder open(M8 Allen bolt 04 nos)	04	Internal
05	Stopper plate open (04 plate M6 Allen 02nos per plate)	06	External
06	Center change	01	Internal
07	Back plate mount	05	External
08	Stopper plate mount	04	External
09	Center holder mount	04	Internal
10	Center inset	0.5	Internal
11	Tail stock declamp/clamp	01	Internal
12	Tail stock center set (M5 06 Allen bolt & 01sensor)	2.5	Internal
	TOTAL	38 min	

By analyzing the operation we breakdown External & Internal Activities in which we are going to avoid the external elements and reduce the. Internal Elements

Internal Means:- Those carried out when the machine has Stopped.

External Means:- Those carried out when the machine is running

Total Internal Activity Time:- 13 min

Total External Activity Time:- 25 min

**TABLE 4: Identification of Internal & External in Phase 2**

SR NO.	ACTIVITY.	TIME(Min)
01.	Center collect	0.5
02.	Allen key set collect	0.5
03.	Center holder open(M8 Allen bolt 04 nos)	1.5
04.	Center holder mount	1.5
05	Center change	01
06.	Tail stock declamp/clamp	01
07.	Tail stock center set (M5 06 Allen bolt & 01sensor)	2.0
	TOTAL	08 minutes

**ACTIVITY FOR CHANGE OVER(AFTER)**

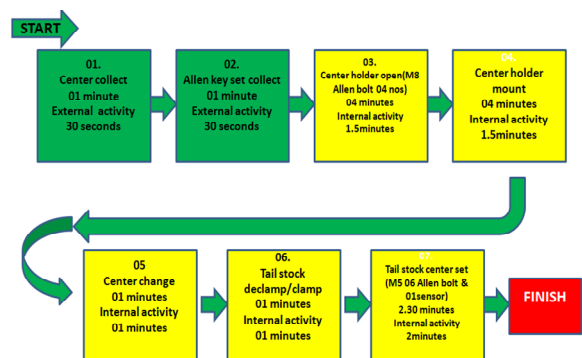
SR NO.	ACTIVITY.	TIME. (Min)	ACTIVITY TYPE.
01.	Center collect	01	Externall
02.	Allen key set collect	01	External
03.	Center holderz open(M8 Allen bolt 04 nos)	04	Internal
04.	Center holder mount	04	Internal
05	Center change	01	Internal
06.	Tail stock declamp/clamp	01	Internal
07.	Tail stock center set (M5 06 Allen bolt & 01sensor)	2.30	Internal
	TOTAL	14.30	

By continual improvement by studied current VSM we find once again the process is bottleneck is same so we will go for next phase to reduce Changeover Time for same. And the Methodology is used is same as the above

Total Internal Activity Time:- 12.5 min

Total External Activity Time:- 02 min

**SMED change over after reducing external activities:**  
Where we convert internal activities to in external activities and continuously working on the same



**Fig.3. SMED Way Map**

### Converting Internal Activity to External Activity:-

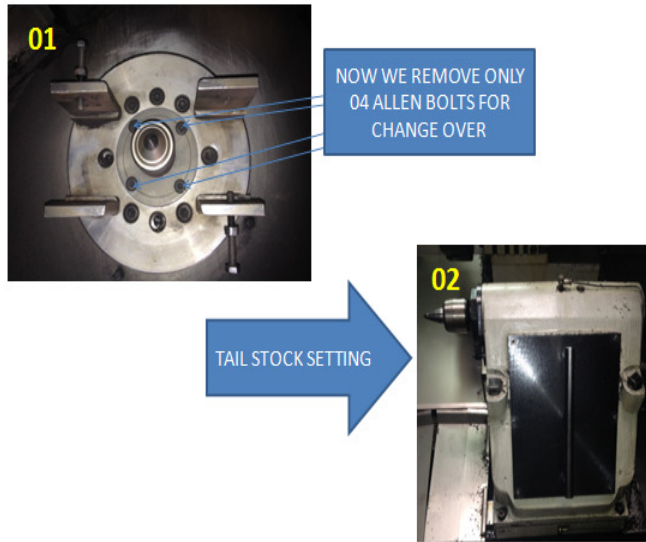
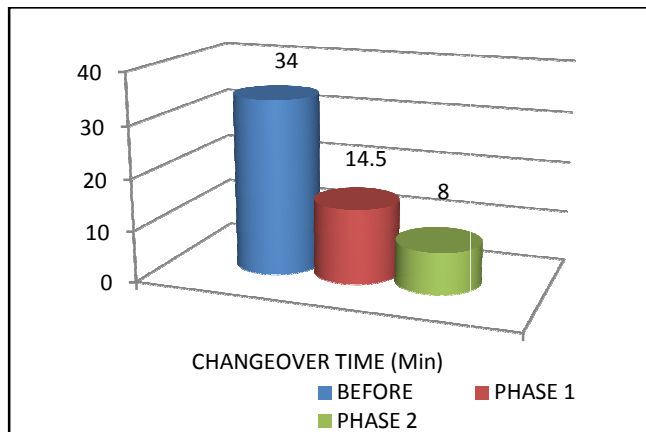


Fig. 4.Process Improvemnt

## 4. RESULTS & CONCLUSION



SMED principles. However, for small batch manufacturers the issues that led to the change in focus for long run producers have not been present to the same degree. SMED methodology applied to prepare an optimal standard procedure for changeover operations on defined machine. A Comparison of results and achievements before and after SMED implementation were made to measure the effectiveness of SMED to reduce cycle time. Hence, not only is it imperative to focus on reducing the amount of

productive time that is lost when a machine is being set, but also to eliminate errors, with the application of poka yoke principles to the setting equipment and procedures.

Productivity improved in Ist phase is about 10 No's of Yoke Shaft in a day and 24 No's of Mid shift Shaft in a day. Due to this improvement and Multi products can be produced in a day in second Phase as per customer demand in existing condition. In which we are giving the equal waightage to all product and capacity to manufacture all the parts gets improved by improving availability and Productivity

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# Implementation of Lean Six Sigma in an Small Scale Sheet Metal Industry

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**Abstract:** *Lean and Six Sigma are two widely recognized business process improvement methodologies available to organizations today for achieving drastic results in cost, quality, productivity and time by focusing on process performance. Lean reduces non value added activities and Six Sigma reduce defects. This paper shows a Lean Six Sigma methodology to reduce the defect occurring in the final product (junction boxes) manufactured by sheet metal forming process. The proposed model integrates Lean tools within Six Sigma DMAIC methodology to enhance the bottom line results and win customer satisfaction. Implementation of this methodology shows drastic improvement in quality of the product, increasing the process flow, on time delivery and a substantial financial savings is generated by the organization. Application of COQ (cost of quality) was also considered as a measuring tool for calculating all the costs and bifurcating them. As a result a new inspection pattern was developed with the revised sampling plans.*

**Keywords:** *Lean manufacturing, Lean six sigma, Six sigma*

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## 1. INTRODUCTION

The last two decades has seen as an increased pressure from customers and competitors for higher value from their noteworthy purchase whether based on quality, faster delivery, or lower cost (or combination of both) in both manufacturing sector (Basu, 2001) (George, 2002). "This has urged numerous industries to adopt either Six Sigma (as their process improvement and problem solving approach) or Lean Manufacturing (for improving speed to respond to customer needs and overall cost) as part of management strategy to increase the market share and maximize profit". All the large companies such as Toyota, Danaher Corporation, General Electric, Motorola, Honeywell, and many others, have accomplished sensational outcomes by executing either Lean or Six Sigma systems in their organization (Basu, 2001) (Muman et al., 2002) (Womack et al., 1990). "Lean manufacturing and the Six Sigma philosophies have been utilized effectively for a long time to produce significant financial savings for companies such as General Electric, Toyota, Caterpillar, and Bank of America, these approaches have only recently started being used in the various manufacturing industry." Each methodology proposes a set of attributes that are prerequisites are essentials for compelling usage of the individual program: top management commitment, cultural change in organizations, good communication down the hierarchy, new approaches to production and to servicing customers and a higher level of training and education of employees (Antony et al., 2003) (Womack et al., 1960). "Most companies using the combined approach apply basic of Lean tools and techniques at the beginning of their program, such as current state map, basic housekeeping

using 5S practice, standardized work, etc." After implementing the above tools and techniques some wastes are eliminated from the system. Now, the tools and techniques of Six Sigma are used to offers better solutions to endless problems. The comprehensive set of tools, techniques and principles that can be employed in the combined approach of Lean and Six Sigma business strategies is delineated in various research papers and books (Basu, 2001) (Breyfogle, 1999) (Pyzdek, 2000) (Rother, 1998). Based on the review of LSS frameworks, it lacks scientific management and lean anchorage is not appreciable (Pepper and Spedding, 2009). One of the noticeable observations is that previous researchers have applied lean tools only during the initial stages (Kumar et al., 2006). Our argument is that both LSS tools and techniques need to be applied across various phases of LSS to obtain the combined powers.

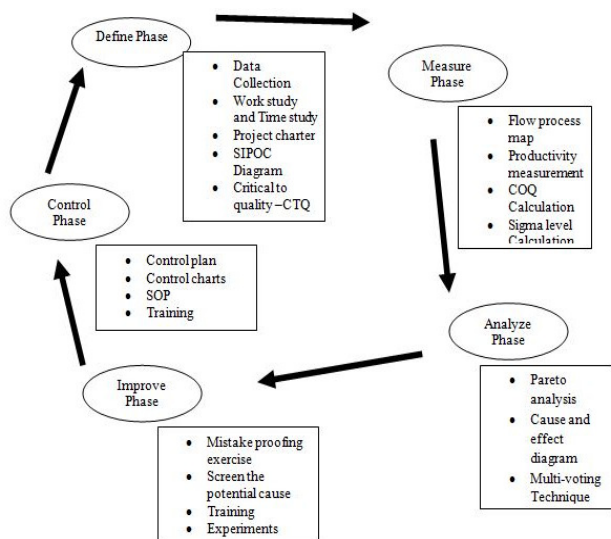
This paper presents a case study undertaken by implementing a Lean Sigma into an Indian small scale sheet metal industry in order to reduce the defects which occur in the final product manufactured by the company that is adaptable boxes (Junction boxes) and thus satisfy their customers. The company was receiving complaints from its customers on various issues such as rusting problem, spot welding failure, gap at the corner of the box, missing thread in clamps etc. This was the major cause of customer dissatisfaction and was putting customer loyalty at risk. Due to the rejection company already had some financial losses. Another problem was late delivery. Therefore main objective of the the company was to control the rejection and increase the productivity.

Further paper is divided in a four section. Section 2 contains the information and background of company where the project is conducted. Section 3 is the step wise methodology. The researcher has explained in the detail about the DMAIC methodology and various tools used in the different phases. The last section that is section 4 is about the result and conclusion which is the outcome of the implementation of Lean six sigma.

## 2. COMPANY BACKGROUND

Established in the year 2002, MDENGINEERS, are engaged as one of the leading manufacturers, exporters and suppliers of a wide range electrical fitting, pipe fitting and electrical components. These are widely acclaimed in Mild steel, corrosion resistance steel and Galvanized metals. Firms range caters to the requirements of Construction Company, Electrical stores and other electrical wiring requirements. The main Product which company is manufacturing is the Adaptable boxes (Junction box) in all sizes. Adaptable box is used for internal wiring purpose in the huge building and construction. Another product is extension rings. Extension rings are also use for extending wires for internal wiring.

## 3. METHODOLOGY



**Fig. 2. Framework for Lean Six Sigma**

The step it follows is called DMAIC (Define, Measure, Analyze, Improve and Control). “First step is to define the process to be improved and after that the performance of the existing process is measured. The performance data is then analyzed, Problematic areas are identified, and after analysis improvement programme is defined and applied.” Industry wants to achieve defect free product at the minimum cost to satisfy customer requirement. Since most of the sheet metal industry processes are automatized, there is an effort to achieve defect free product as close to 100%.

“Due to this reason, industries are integrating lean and Six Sigma techniques. The figure is a framework model for the project by which we can get brief idea about the DMAIC methodology and various tools which was used in different phases.”

### 1) Define Phase:

Define is the initial phase of the DMAIC methodology. A selected problem should have a strategic impact on organization performance, also it should relate to the business goals of organization as well linked with the consumer requirement. In define phase, tools used are the data collection, Work study and time study, Project charter, SIPOC diagram and Critical to Quality tree. In data collection, it was found out that which size of box is contributing more in the annual turnover of the organization; hence we work on that size in order to get break through improvement. Work study and time study was done to understand the whole process of manufacturing the box and to find bottleneck activities in terms of cycle time and hence the process which consumes more time. Project charter gives us idea about the project targets and goals. SIPOC (supplier, input, process, output, customer) diagram helps to understand the relation between the supplier, process and customer, hence it is the high level process map. A number of brainstorming sessions were conducted to identify critical to quality (CTQ) characteristics based on the voice of customer (VOC) input. Generally voice of customer is all about to understand the problems and hurdles which customer are facing. The main CTQ drivers to get defect free product were as follow as:

- Rust free product
- No spot welding failure
- No gap at the corner of the box
- Zero thread in clamp
- Moist free cartons.

### 2) Measure Phase

“Nothing can be improved until and unless it is measured.” Measurement system will provide baseline for improvement, also identifies significance level of criticality pertaining to problem selected. In Measure phase, Flow process mapping, Productivity measurement, COQ calculation and Sigma level calculation. Flow process map is a process mapping tool which is similar to value stream mapping. Flow process map helps to study all the process in detail including all the metrics such as cycle time, lead time and daily capacity of production. It was identified that the that assembly and packaging and spot welding process were the bottleneck process in terms of cyclic time and daily based production. Productivity measurement was also done, in that various productivity such as labour productivity,

energy productivity, material productivity and total productivity was calculated. The method of calculating productivity is different in different books and research paper. Some authors develop their own model for calculating productivity. COQ Cost of quality calculation were done, in this all the costs of the company were bifurcated into the all four costs that is Prevention cost, Appraisal cost, Internal failure and External failure. Finally the Sigma level calculation was done and the sigma level (before) was 4.51.

### 3) Analysis phase

The objective of this phase is to find out the root causes of defects and identify the significant process parameters causing the defect. The tools used in this phase are Cause effect diagram-root cause analysis multi-voting technique and why-why analysis. Cause and diagram is often called fishbone diagram, which utilizes a show looking like the bones of a fish to order potential causes and represent the levels of causation. Fishbone diagram was made for every cause separately to get perfect root cause. After the fishbone diagram the multi voting was done. Multi voting is technique in which the 5 members were selected to vote that which of cause is critical. These members are highly involved in the project as well as there are important bodies

of the organization. Finally the rating was given out of 5 to every sub causes from the fishbone diagram. The next step in this phase is the why why analysis. "By repeatedly asking the question "Why" (five is a good rule of thumb), we can peel away the layers of symptoms which can lead to the root cause of a problem." All the time the probable explanation behind a problem will lead us to another question. Despite the fact that this system is called "5 Whys," it may find that it should ask the question less or a bigger number of times than five preceding you discover the issue identified with a problem.

### 4) Improve Phase

This is the phase of the project where all the team's work gets put into action and the rubber meets the road for hard driving. The solutions have been identified and the implementations to reduce variation and improve target performance are executed". Without making the improvements, all the hard work and invested time amounts is nothing. After conducting several brain storming session and discussion with some of the expertise, the corrective action as an improvement for the root causes were decided to be implemented. The below table 2 was prepared to get idea that what was root cause and what was the implementation action against it.

**TABLE 2: Root cause and Corrective action table**

ROOT CAUSE	CORRECTIVE ACTION
Improper drying system at vendor side	Multiple sourcing and Taken the confirmation vendor that he will supply dry corrugated box.
Lack of moisture locking packaging	Experiment of perfect amount of silica gel
Improper number of brush usage and low quality of brush.	Experiment is conducted for correct number of brush to be use
Change of operator frequently and unskilled worker	Standard operating procedure for spot welding and training session for other workers.
Improper tool setting – stroke setting of press	Chart must be prepared in which perfect gauge length stroke height must be written for every box.
Improper gauge setting – jigs and fixture	Poka-yoke and mistake proofing exercise .A template must be developed for setting the gauge for corner cutting.
Missing thread in clamps	Different color carat must be used.

### 5) Control phase

The last stage of Six Sigma's DMAIC model is the Control stage. The concentration of this stage is to ensure that the activity thing made in enhance stage is very much executed and implemented. The initial step of this phase is the control plan, hence control plan was prepared and in this control plan there is sample size, data description, corrective action etc is mentioned. After that the next step is the control charts. The control chart is a graph or chart used

to understand how a process changes over time. Data are plotted in time order. "A control chart always has a central line for the average or mean, an upper line for the UCL(upper control limit) and a lower line for the LCL(lower control limit)."As the data were attribute, NP control chart was prepared. Almost all the processes were under control. The new inspection method was developed, in this inspection method the parameter for inspection were changed as per the customer needs and company requirement. This increase the Appraisal cost and the result

is outrageous that there no external failure and no customer complains.

#### 4. RESULT AND CONCLUSION

In current project, the Critical to quality parameters where given by the customer, so the researcher identifies the root cause for the all CTQs and had solved all the problems and defects which were mentioned in CTQ. The researcher also used the various tools and application in a project such as flow process map, root cause analysis, SOP, Why-Why analysis etc. Along with tools researcher has used Minitab software's for data requisition and analysis.

The Project suggested and implemented various improvements which increase quality and productivity of the company. The results of improvement are as follow as:

- After implementation of Lean six sigma, the researcher improved sigma level from 4.31 to 4.71. The researcher conducts the cost of quality analysis and calculate the various cost and bifurcate them.
- As a result of COQ analysis, the researcher increase the appraisal cost by developing new inspection format and technique which built up good customer satisfaction by reducing defects.
- The researcher find out the bottleneck process in terms of cycle time from the whole manufacturing process in the company and successfully improve it from 23.5 days to 21 days.
- By the application of lean six sigma, the researcher was successful in decreasing the rejection rate from 1.2% to 0.3%. The result of the project gives out the annual cost saving of Rs133486 to the company.

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# Review of Lean Manufacturing Philosophy in Manufacturing SMEs to Identify Critical Success Factors

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**Abstract:** Most of the manufacturing industries have been facing challenges of rapidly changing set of market requirements and demand. For developing countries such as Indian manufacturing industries to stay in competition and maintain their market share in this global market, the adaptation of lean manufacturing system has become essential. Lean Manufacturing focus on the systematic elimination of waste and non-value added activity from the production process, reduce time and cost for improved operational and financial performance. Although many firms are attempting to implement lean, only an estimated very few percent are achieving the desired level of success. The comprehensive literature review method has been adopted for the study. This study will provide current status of Lean Manufacturing principle and accompany the organization to prepare framework to identify the critical success factors (CSF) that constitute a successful implementation of lean Manufacturing within manufacturing small and medium enterprise (SMEs).

**Keywords:** Lean Manufacturing (LM), Critical success factors (CSF), Manufacturing industry, Small and medium enterprises (SMEs), Developing countries

## 1. INTRODUCTION

### 1.1 Lean Manufacturing Overview

Lean manufacturing concepts were developed over the last five to six decades, primarily in Japan, particularly for the Toyota production system. Lean manufacturing revolutionizes the manufacturing process (Jain and Malik, 2013). Lean manufacturing is a systematic approach for eliminating any type of waste from manufacturing operations (Salonitis and Tsinopoulosb, 2016). These wastes are defined as waste or muda of Lean: T—

Transport—moving people, products, and information; I—Inventory—storing parts, pieces, documentation ahead of requirements; M—Motion—bending, turning, reaching, lifting; W—Waiting—for parts, information, instructions, equipment; O—Overproduction—making more than is IMMEDIATELY required; O—Over-processing—tighter tolerances or higher grade materials than are necessary; D—Defects—rework, scrap, incorrect documentation (Roberta S. Russell, Bernard W. Taylor III, 2011, Operations Management, John Wiley and sons, Inc). Lean Manufacturing forms house as shown in fig. 1

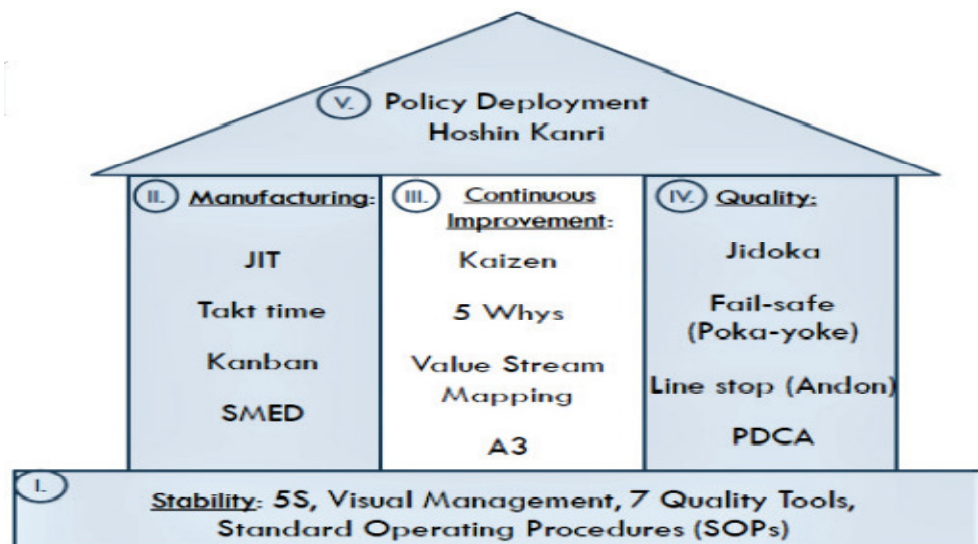


Fig. 1. House of Lean (Jones DT and Womack J., 1996)



## 2. LITERATURE REVIEW

Literature review has been carried out by comprehensively studying research papers and case studies published in various international journals from prominent publishers

Elsevier, Emerald, Taylor and Francis, Springer to name a few. Brief description of research work carried out by researchers till now in the field of Lean Manufacturing is furnished as follows:

**TABLE 1: Literature review on Lean Manufacturing philosophy**

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
1	Salonitis and Tsinopoulosb	2016	The analysis of the questionnaires developed revealed the level of understanding, the key barriers and drivers behind lean implementation success.   <b>CSF:</b> Organizational culture and ownership, Developing organizational readiness, Management commitment and capability, Providing adequate resources to support change, External support from consultants in the first instance, Effective communication and engagement, Strategic approach to improvements, Teamwork and joined-up whole systems thinking, Timing to set realistic timescales for change and to make effective use of commitments and enthusiasm for change   <b>Barriers:</b> Top management related barriers(Poor commitment from top because of poor knowledge/ understanding, poor belief on the approach/ advantage, change inertia, top management commitment lasted too shortly), Financial barriers (Necessity of high investment/ cost), Workforce related barriers (Employee's fear of job cutting, change inertia, change was not shared, poor knowledge / understanding), Other barriers (Distractions/ slow down due to fire fighting on other project / problems, multiple production sites, difficulty in quantifying the benefits upfront.
2	Sisson and Elshennawy	2015	The final, tested model can provide companies wishing to implement lean with a framework for implementation.   <b>Key Factors:</b> Deployment, Engagement, Training, processes, Drivers, Culture
3	Achanga et al.	2006	CSF: Leadership and management, Financial capabilities, Skills and expertise, Organizational culture
4	Netland	2015	To succeed with implementing a lean program in a factory, managers must commit to and involve themselves in the activities of implementation. Such active leadership must be sustained – and even intensified – as implementation progresses. Developing lean knowledge and competency by offering continual education and training to both managers and employees is critical for success. External resources can be used early on, but they will have a more limited effect when plants reach higher implementation stages. Furthermore, there is a persistent need for proper planning, following-up and funding of the lean program. In the early stages of implementation, sharing best practices and establishing a dedicated implementation team can be effective. As implementation progresses, these factors become less important and managers should plant-wide routines by increasing the empowerment of shop floor employees.   <b>CSF:</b> Management commitment and involvement, Training and education, Employee participation and empowerment, Alignment to strategy and long term plan, Managing cultural change, Supplier involvement, Customer involvement, Teamwork, Process management, Structured approach and

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			project prioritizing, Benchmarking and knowledge transfer, Cross functional integration, Quality data and analysis, Project management skills, Performance measurement, Organization infrastructure, Sustain continuous improvement, Quality control and robust process, Use of tools, techniques and technologies, Communication, Reward and recognition, Job security and social responsibility
5	Hibadullah et al.	2014	<b>CSF:</b> Supplier management, Employee involvement, Just in time, Customer focus, Statistical process control
6	Dora et al.	2015	<b>Determinant Factors:</b> Commitment of top management, Culture, Piecemeal approach, Training, Multifunctional team, Resource, Organizational structure, Remuneration, Change agent, Nature of the process, Nature of product, Nature of the plant
7	Sangwan et al.	2014	The study identified 12 drivers for the LM implementation in Indian ceramic industry. Further, these 12 drivers have been categorized into internal, policy and external drivers (ED). Structural model affirms that ED are positively related to policy drivers (PD) and PD are positively related to internal drivers.   <b>Drivers:</b> High level of stock/inventory, Low manpower productivity, Poor skills/capabilities of workers, Unavailability of skilled workers, High labor cost, High scrap/rework/rejection, Poor commitment of employees, Customer wants reliable and prompt deliveries, Fluctuating customer orders, High product variety/ customer specific products, Unbalanced workload on different workstation, Poor workplace organization and housekeeping, High cost of energy (electricity or fuel cost), Weak process control, Low capacity to fulfill the regular demand of customers, Lack of standard operating procedures, Short time to fulfill customer orders, Low quality material or parts by suppliers, Suppliers take long time to deliver, Frequent changes in supply schedule by customers
8	Patri and Suresh	2017	The study suggests that leadership is the most crucial factor for lean implementation success and availability of adequate training, acts as a catalyst.   <b>CSF:</b> Lean leadership, Frontline workforce engagement, Inter departmental co-operation, Lean training, Time commitment for lean implementation, Professional culture, Notion of inappropriateness of lean system in healthcare, Notion of lean implementation as cost cutting and layoffs, Goal specificity, Healthcare organizational resistance
9	Azyan, Pulakanam, Pons	2017	<b>Success Factors:</b> Strategic need, Organizational size, Leadership, Management commitment, Finance, Organizational culture, Employee participation, Skills and expertise, Tools and Methods
10	Elnadi and Shehab	2015	<b>Enablers:</b> Supplier relationship, Management quality, Employee quality, Work process, Management status, Customer relationship
11	Jie Ma Zhibin Lin Chi Keung Lau	2017	The results of the study indicate that Personnel factor enablers are the most important factor for Kaizen, whilst Software factor enablers (essential rules, policies and institutional arrangements) weight second and Hardware factor enablers (physical, measurable hard facts or resources) weight last. The study also reviews that Kaizen is the most selected improvement method among the three.   <b>Enablers:</b> The hardware factor enabler, (Monetary investment, Technologies, Machinery equipment, Experts/ Consultant), The software factor enabler (Training / Job rotation, Open communication, Incentives / Rewards, Standard

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			procedures, Improvement culture, Improvement system, Benchmarking / feedback, Shop floor management), The personnel factor enabler (Top managers, Middle managers, Line managers, Shop floor personnel, Non production personnel)
12	Noori	2015	<b>CSF:</b> Strategic orientation and leadership infrastructure, Culture, Management system, Implementation process, Implementation team
13	Stone	2012	Factors: Leanness, Transformational, External environment, Mission and strategy, Leadership, Culture, Performance, transactional, structure, management practices, System, Climate, Task / skill, Motivation, Need and values
14	Sim and Rogers	2008	Results from the survey show that the problem lies primarily with an aging and high seniority hourly workforce and a lack of committed leadership at this research site. For example, salaried employees consistently provided higher positive ratings of CI initiatives. In addition, higher seniority was directly correlated with negative ratings. Finally, the study found that employees do not feel valued when they contribute to the improvement processes and that 100 per cent of the hourly male employees disagreed that “The Company considers the employees as the most important asset and will do whatever they can to keep their people”.  Managerial implications
15	Shang and Pheng	2014	<b>Barriers:</b> Lack of long term philosophy, Absence of lean culture in the organization, Limited use of D&B procurement mode, Construction firm’s limited involvement in the design, Insufficient knowledge of lean, Multi-layer subcontracting, Limited use of site construction technique, Insufficient management skills, Lack of support from top management, High turnover of workforce, Insufficient training, Employee and management resistance to change, Employee tolerance of untidy workplace, Absence of lean culture in partners, Inadequate delivery performance, Hierarchies in organizational structure, Less personnel empowerment, Avoid making decisions and taking responsibility, Using guanxi or relationships to conceal mistakes, Stringent requirements and approvals, Lack of support from government
16	Jadhav et al.	2014	<b>Barriers:</b> Top management resistance, Lack of top/senior management focus, leadership, Lack of top/senior management involvement (commitment and support), Lack of communication between management and workers, Lack of empowerment of employees, Workers’ resistance, Lack of perseverance, Lack of consultants and trainers in the field, Lack of formal training for managers, Lack of formal training for workers, Cultural difference, Lack of cooperation and mutual trust between management and employees, Cross-functional conflicts, Incompatibility of lean with the company bonus, rewards or incentives systems, The lack of resources to invest, Slow response to market, Lack of information sharing or communication with suppliers and customers, Lack of cooperation from suppliers, Lack of influence over suppliers or lack of involvement of suppliers in the actual implementation, Lack of supplier collaboration or lack of mutually beneficial strategic partnership with suppliers and customers (supply chain members), Quality problems with supplied material, Absence of a sound strategic action/logistical planning system, Lack of logistic support, Problems with machines and plant configuration
17	Amir H. Abolhassani Ky Layfield Bhaskaran	2016	<b>Implementation Difficulties:</b> Sample demographics, Facilities’ size and years of lean strategic practice, Most Beneficial and least difficult lean strategic

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
	Gopalakrishnan		practiced, Level of implementation for the most beneficial lean strategic practices, Difficulties for implementing lean strategic practices, Difficulties of implementing lean for practitioners, Difficulties for implementing lean of non-practitioners
18	Lodgaard et al.	2016	<b>Barriers:</b> Management, Knowledge, Organizing for lean, Use of tools and practices
19	Dora et al.	2013	<b>CSF:</b> Leadership and management, Organizational culture, Skill of the workforce and in-house expertise, Financial capabilities
20	Bortolotti et al.	2014	<b>Culture dimensions:</b> Power distance, institutional collectivism, In-group collectivism, Future orientation, Performance orientation, Gender egalitarianism, Assertiveness, Uncertainty avoidance, Humane orientation
21	Marodin and Saurin	2017	The main contribution of this study is the framework for managing barriers to LPI, which consists of normative theory for LPI. Such type of theory refers to the development of guidance about what actions will and will not lead to the desired result. The proposed guidance refers to the steps to identify, analyze the relationships, prioritize and control barriers to LPI, taking into account the role of context. Data analysis also allowed the emergence of a meta-prescription, namely that the process of LPI, and thus the management of barriers, should adopt lean principles.   <b>Barriers:</b> People seem demotivated after a few years, Lack of human and / or financial resources, Difficulties in seeing the financial problems, middle management not giving enough support, Top management not giving enough support, Lack of support on the shop floor, Operators are insecure in carrying out new attributions, Operators are afraid of lay off due to improvements, The operators do not feel responsible for using lean practices and solving problems, Managers lack technical knowledge and skill to guide the LPI, Not sustaining the improvements in the medium and long term, Having difficulties to keep the pace of the ongoing LPI activities.
22	Bhasin	2012	<b>Obstacles:</b> Culture, Past history of initiatives, Staff attitudes, operative resistance, Unique of lean journey, View lean as long term journey, Lean not synonymous to lean tools, Lean applied to the value chain, Cost of implementation, Measuring the benefits of lean, View lean as business proposition, Traditional cost accounting system, Internal communication system,   Backsliding to old methods. Insufficient supervisory skills to implement lean, Employee attitudes/resistance to change, Insufficient workforce skills to implement, lean Insufficient senior management skills to implement lean Insufficient management time, Cultural issues, Cost of the investment, Insufficient understanding of the potential benefits, Insufficient internal funding, Insufficient external funding, A need to convince shareholders / owners
23	Rane et al.	2016	<b>Barrier:</b> Health issue, Lack of multitasking, Leadership and management, Monotony, Communication, Resistance toward lean implementation, cultural differences   <b>Enabler:</b> Top management support, Shared vision, Expertise, Transparency, Predictability   Driver: Knowledge, Can do attitude, Compensation, Education and training,

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			Empowerment, Employee involvement, Competitor, Trust, Motivation, Teamwork
24	Losonci et al.	2011	<b>Factors:</b> Lean success, Commitment (Feeling of involvement), Belief, Work method, Communication
25	Singh et al.	2012	<b>Customers issues:</b> To reduce response time, To deliver in small lots, To implement self-certification, To reduce rejection, To increase range of products   Organizational issues: Frequent breakdown, High inventory, High rejection rate, Underutilization of capacity, Workers absenteeism, Obsolete technology, High setup time/changeover time   <b>Supplier issues:</b> Unreliable transport, Frequent changes in supply schedule, Poor communication system, Poor vendor response, Frequent design changes, High lead time, Market issues, Stiff competition, Low sales revenue, Poor brand image   <b>Top management issues:</b> Lack of funds, Lack of multi-skilled manpower, Lack of quality consciousness, Lack of support from top management
26	Taj	2008	Factors: Inventory, Team approach, Process, Maintenance, Layout and handling, Supplier, Setup, Quality, Scheduling / Control
27	Naga Vamsi Krishna Jasti Rambabu Kodali	2016	The major constraints to implement LM principles were employee resistance and lack of awareness about LM principles among industry professionals. The study also revealed that majority of the organizations have implemented in specific area of the manufacturing operation with very few popular tools of LM instead of following any systematic approach to implementing LM principles across whole organization.
28	Almanei, Salonitis, Xu	2017	<b>CSF:</b> Top management, Training and education, Thinking development, Employees, Working culture, Communication, Resources, Customer focus, Government intervention   <b>Challenges:</b> Organizational culture and ownership, Developing organizational readiness, Management commitment and capability, Providing adequate resources to support change, External support from consultants in the first instance, Effective communication and engagement, Strategic approach to improvements, Teamwork and joined-up whole systems thinking, Timing to set realistic timescales for change and to make, effective use of commitments and enthusiasm for change
29	Anna Dorota Rymaszewska	2014	<b>Challenges:</b> The challenge of long-term orientation, The challenge of becoming a learning organization, The challenge of leveling out workflow, The challenge of supplier-buyer relations and JIT, The challenge of employee empowerment and standardization of the work procedures
30	Kumar and Antony	2008	Differences in quality management practices such as customer focused measures and method of knowledge transfer to employees, were observed in Six Sigma and ISO certified SMEs. The main reasons cited for not implementing Six Sigma in SMEs were lack of knowledge or understanding of the system and limited resources. A significant difference in the performance of Six Sigma/lean firms against ISO certified companies were observed with respect to the strategic and operational measures of organizational performance   <b>CSF:</b> Management involvement, Communication, Link QI to employee, Cultural change, Education and training, Link QI to customer, Project

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			selection, Link QI to business, Link QI to supplier, project selection, Link QI to business, Link QI to supplier, project management skill, Organization infrastructure, Vision and plan, It and innovation Barriers: availability of resources, Lack of knowledge, Lack of training, Internal resistance, Poor employee participation, Inadequate process control technique, Changing business focus, Lack of management commitment, Poor delegation authority, Poor supplier involvement, Poor project selection
31	Garcia et al.	2013	<b>CSF:</b> Commitment and motivation of staff Support from senior management, Allocated resources (time, economic, spaces), Leadership, Developing culture of continuous improvement, Set goals for improvement programs, Using an appropriate methodology, Standardization and process measurement, Organization of support teams, Presence of a facilitator to support the program, Interdepartmental communication, Differences between the focus of improvement and the existing culture, Employee attitude, Interdepartmental cooperation, Follow the PDCA cycle, Training and education, Heterogeneity of improvement teams, Assessment system, Skills and experience, Establish policies, objectives and structure, Clarify goals and common ideas
32	Shaaban and Awni	2014	<b>CSF:</b> Leadership style and influence, Management commitment, Clear vision and integrated strategy, Existence of strong motive (burning platform), Availability of financial resources, Level of knowledge and experience, Organization culture, The role of consultant, Benchmarking and sharing best practices
33	Clegg et al.	2010	Critical success factor statements for quality management are agreed with, although not all are implemented well. The findings also show that many quality tools are not known or understood well; and that training has an important role in raising their awareness and making sure they are used correctly.
34	Praveen Goyal Zillur Rahman Absar Ahmad Kazmi	2015	A total twelve important practices were identified with the help of a literature review and expert opinions. The relative importance of the different practice on different dimensions of corporate sustainability was identified by using the AHP technique. With the help of experts, major corporate sustainability practices for a manufacturing sector were identified.
35	Khanna et al	2011	<b>CSF:</b> Top management commitment, Role of quality department, Process quality management, Product/service design, Education and training, Supplier quality management, Customer satisfaction, Employee empowerment and involvement, Business/quality results, Information and analysis, Benchmarking, Quality citizenship, Quality culture
36	Yadav and Desai	2016	<b>Barriers:</b> Lack of top management attitude, commitment and involvement, Lack of training and education, Poor project selection and prioritization, Lack of resources (financial, technical, human, etc.), Weak link between the CI projects and the strategic objectives of the Organization, Resistance of culture change, Poor communication, Lack of leadership skills and visionary and supportive leadership, Lack of consideration of the human factors, Lack of awareness of the benefits of Lean/Six Sigma, Wrong selection of Lean/Six Sigma tools, Narrow view of LSS as a set of tools, techniques and practices, Lack of understanding of the different types of customers / VOC, Lack of employee engagement and participation/lack of team autonomy, Lack of process thinking and process ownership, , High implementation cost, Lack of experience in Lean/ Six Sigma project implementation, Lack of awareness of the need for Lean/Six Sigma, Ineffective project management, Poor selection of



Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			candidates for belts training, Lack of clear vision and a future, Lack of an effective model or roadmap to guide the implementation, Time consuming, Lack of estimation of implementation cost, Weak infrastructure, Replicating another organization's Lean/Six Sigma strategy, Lack of a performance measurement system, Lack of application of statistical theory, Weak linking to suppliers, Misalignment between the project aim, the main goals of the company and the customer demand.
37	Faisal Talib Zillur Rahman	2015	The synthesized results have highlighted that the barrier 'lack of communication' is the most significant among all the other barriers. It is followed by 'lack of top-management commitment', 'employee's resistance to change', and 'lack of coordination between departments'. The least significant barrier is found to be 'high turnover at management level'.   <b>Barriers:</b> Attitude of employees towards quality, Employee's resistance to change, High turnover at management level, Human resource barrier, Inadequate use of empowerment and teamwork, Lack of communication, Lack of continuous improvement culture, Lack of coordination between department, Lack of proper training and education, Lack of top-management commitment, No benchmarking, Poor planning
38	Garcia et al.	2014	Management commitment and Education and training are the basis or pillar for a successful kaizen implementation program and that its performance can be measured by best process, workers and customer satisfaction.   <b>CSF:</b> Commitment and motivation of staff, Support from senior management, Allocated resources (time, economic, spaces), Leadership, Developing a culture of continuous improvement, Set goals for improvement programs, Using an appropriate methodology, Standardization and process measurement, Organization of support teams, Presence of a facilitator to support the program, Interdepartmental communication, Differences between the focus of improvement and the existing culture, Employee attitude, Interdepartmental cooperation, Follow the PDCA cycle, Training and education, Heterogeneity of improvement teams, Assessment system, Skills and experience, Establish policies, objectives and structure, Clarify goals and common ideas
39	McNamara	2014	Research has found that human beings are limited in their ability to process information (Simon, 1976). For instance, investors often fall prey to herding behavior and decide based on what others have chosen. They are fooled by randomness and underestimate its impact on their financial decisions (Shiller, 1984; Olsen, 1996). Likewise, management in all its forms should be made aware of cognitive biases and their effects on decision making; hence, relevant psychology training programs need to be created. All individuals who make decisions in an organization are subject to biases; therefore, management and those who make the most important decisions should be especially aware of the different types of biases that affect their own personal decision making capabilities.
40	Andre Luís Helleno, Aroldo José Isaias de Moraes, Alexandre Tadeu Simon		The conceptual method brings a new group of indicators associated with economic, social and environmental dimensions, which, together with the traditional indicators of VSM (Lean KPIs), seek to assess manufacturing processes and thus generate actions of continuous improvement (Kaizen) to develop sustainable manufacturing processes. The application of VSM identified the need for increased efforts in collecting data in relation to the traditional VSM. This is because information related to the economic, social

Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			and environmental dimensions are not monitored in the manufacturing process but rather by other departments, such as accounting, human resources, work safety and environmental management.
41	Antosz and Stadnicka	2017	The results show that many of SME are ready to implement Lean Manufacturing philosophy. These companies want to improve their operation or they realize the need of waste elimination. The major wastes are: waiting for material (49%), unnecessary movements (41%) and machine failures (39%). The key reasons for implementing LM are: the intention to improve the company's operation (81%) and the need to gain a competitive advantage (50%). However, still many of the companies (55%) do not implement the LM philosophy whereas the companies which have implemented the LM philosophy use mostly 5S method (29%).
42	Bin Zhou	2012	Results demonstrate that most of the firms have a relatively good understanding of lean concept and philosophy. Majority of the firms regard lean as costs savings, continuous improvement, and waste reduction. It was also found that the main driving factors that encourage SMEs to implement lean are: cost reduction, improve profit margin, reduce inventory and assets required, improve utilization of plant/facility, and maintain competitive position.
43	Jain and Malik	2013	This paper presents a review of lean manufacturing adopted by manufacturing organizations. It has been established beyond doubt that to remain in business it has now become the necessity for all the industries especially Indian SME's to adopt the tools of lean principles. Indian small scale industries have to shed off their conservative attitude and should reform their working practices with lean tools. Attitude of work force in these industries also requires a lot of cultural change to save their livelihood.
44	Panwar et al.	2015	It is observed that the level of implementation of lean manufacturing in Indian process industries is still low. Results indicate that Indian process industries those who have implemented lean found lean to be very useful to reduce wastes and to increase quality. Major lean practices being implemented by Indian process industries are primarily those which are related to waste elimination or improvement in quality. Indian process industries found that important challenges to implement lean are to produce in small batches, to arrange for lean experts and to impart training to employees.
45	Ravikumar et al.	2016	The SEM enhances its significant use with the perfect interrelationship between the performance factors though they are found to be only significant in the interaction between the criteria. The ranking obtained from TOPSIS and fuzzy TOPSIS is useful for the industries to pay their attention on some important issues while achieving the prescribed targets.
46	Panizzolo et al.	2012	Six areas for assessment of lean Manufacturing implementation have been discussed to identify operational benefits gained by organizations: Process and equipment, Manufacturing planning and control, Human resources, Product design, Supplier relationships
47	Sharma et al.	2016	Through extensive literature review and discussions with industry practitioners, this research identified 8 criteria for lean implementation at a brainstorming session of experts from automobile and machine tool sector. These include 5S, VSM, JIT, SMED, CIM, CE, training and ERP. ISM methodology is used to develop the structural model by creating SSIM, reachability matrix, level partitioning, and finally formulation of the model. MICMAC analysis is employed to establish the driving power and dependence



Sr. No.	Authors	Year	Main Findings & Critical Success Factors
			powers of the 8 identified lean implementation criteria.
48	Dibia et al.	2014	The LPPO model is a Lean implementation model that is flexible and easily adaptable. It is system based, people driven, customer centered, with measurable outcome and a drive for continuous improvement.
49	Dombrowski and Mielke	2014	In this paper, the attributes of a true CIP were described and some basic lean leadership approaches were explained. Based on these approaches, 15 practice-oriented requirements were identified, that could be derived from study results and various references regarding advices, error reports and deficits in leadership during lean implementations. These new requirements were framed as rules for lean leaders to support their daily efforts toward a true continuous improvement.
50	Alefari et al.	2017	In the present paper, the importance of top management and leadership in the introduction and implementation of lean manufacturing has been discussed. Based on a survey undertaken within the UK manufacturing sector, top management has been highlighted as the key success factor, particularly for SMEs. A number of expectations from the management were discussed such as the top management commitment, the selection of the appropriate leadership style, the engagement and development of capable lean employees.
51	Worley and Doolen	2015	The effects of Organization structure and employee problem solving skills has been discussed in detail that how does it influence Lean Manufacturing implementation and its successful continuation.

### 3. DISCUSSION AND FUTURE SCOPE

After going through comprehensive literature study it has been clear that Lean Manufacturing principles are significantly important for the industries desire to improve operational and financial performance by eliminating non value added activities (NVA) and wastes. It has been prominent to adopt the Lean tools to make the organizations viable efficiently for longer time in the market. It has now become the inevitable for all the industries especially Indian manufacturing SMEs to adopt the tools of lean principles. Indian SMEs have to leave conservative attitude and should reform their operation practices with lean tools. Attitude of work force in these industries also requires a lot of cultural change to save their livelihood (Jain and Malik, 2013). Although many organizations try to implement the Lean Manufacturing tools only few of them have completely understand the process and have prepare framework accordingly to execute the Lean Manufacturing practices. It is essential for organizations to assimilate entire concept of Lean Manufacturing which are willing to implement it in order to successfully achieve the potential benefits of the philosophy. Firms should give equal importance in consideration of critical success factors (CSF), because if the CSF are considered appropriately it will ensure success and sustainability of Lean Manufacturing practice. Research have also suggested that top management commitment and support, Organizational culture and Leadership style are the profound factors in achieving

success with Lean. To succeed with a lean program in a factory, top management commitment and involvement is important. Dynamic and persuasive leadership must be sustained throughout the process progress. In order to evolve continuously organization should arrange education and knowledge development program relentlessly. The cross functional ability of the team member can be the asset for the firm to support internal manufacturing operations and other operations as well. It also ensure quick return on investment for the projects as team members are well aware of competition forces and market dynamics. The study suggests that leadership is the most crucial factor for lean implementation success and availability of adequate training, acts as a catalyst (Patri and Suresh, 2013). Results from the study show that the problem lies primarily with an aging and high seniority hourly workforce and a lack of committed leadership at this research site (Sim and Rogers, 2008). Within the UK manufacturing sector, top management has been highlighted as the key success factor, particularly for SMEs. A number of expectations from the management were discussed such as the top management commitment, the selection of the appropriate leadership style, the engagement and development of capable lean employees (Alefari et al., 2017). On the other hand factors such as financial capabilities, Employee training and knowledge, Organizational readiness, Communication, Employee involvement and engagement, Cross functional team development to name a few should be considered carefully as well. The results show that many of SME are

ready to implement Lean Manufacturing philosophy and desire to increase their activities or they identify the need of waste elimination. The major wastes are: waiting for material (49%), unnecessary movements (41%) and machine failures (39%). The key reasons for implementing LM are: the intention to improve the company's operation (81%) and the need to gain a competitive advantage (50%). However, still many of the companies (55%) do not implement the LM philosophy whereas company mostly use 5S method (29%) (Antosz and Stadnicka, 2017).

#### 4. CONCLUSION

It has been clear that Lean Manufacturing principles are significantly important for the industries desire to improve operational and financial performance by eliminating non value added activities (NVA) and wastes. Through the comprehensive literature review it has been clear that very few attempt has been made to identify the critical success factors (CSF) for successful and sustain implementation of Lean Manufacturing philosophy in the manufacturing SMEs in India and global as well. Study has also suggested that organization willing to attempt implement Lean Methodology should carefully consider critical success factors and carefully evaluate organizational capabilities to allocate the available resources in the most effective and efficient manner. Most important barriers to overcome are: Top management related barriers, poor belief on the approach/ advantage, change inertia, top management commitment lasted too shortly, financial barriers, Timing to set realistic timescales for change and to make effective use of commitments. Organization should also consider inter-relation between the critical success factors (CSF) to identify their effects on the entire methodology to successfully attempt Lean Manufacturing practices.

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# Just in Time Can Accrue Benefits to Service Sector: A Review

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**Abstract:** With increase in reliability of the product the customers' expectations has evolved towards achieving full satisfaction with the product and service they purchase. As a result of this many manufacturing and service industries have pointed their focus on customer satisfaction and quality of products and services. Just-In-Time (JIT), the dignified process of waste reduction has been a very popular operational strategy because of its success in the manufacturing and production industry over many years. Various benefits like, improved operational efficiency, waste reduction and faster response have been widely recognized by various researchers globally. Services are much like manufacturing as both culminates in some sort of value addition to the input to achieve desired output. Therefore, successful implementation of JIT is vital to manufacturing as well as service industries. JIT focuses on the processes and not on the final product. Therefore it can be successfully applied to every process within the domains of manufacturing and service sector. This paper evolves a structured review for implementing JIT processes in the service sector, with a goal of investigating how JIT principles can be implemented in service sector.

**Keywords:** Just-in-Time (JIT), quality, cost, service sector

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## 1. INTRODUCTION

Today customers wants quick response to their demand. Waiting in line or otherwise can irritate them or cause inconvenience to the them. With increased global competition and networking facilities customer want quick response to their demand at low costs. Hence, Just in Time which has emerged as a successful tool for reducing production time and wastages in manufacturing industries, can be implemented in service sector as well like hospitality, banking, railways, telecom & airlines. JIT can also be implemented in healthcare, but in healthcare we can't keep limited amount of medicines on our hand and also number of patients cannot be forecasted.

Sometimes customer directly have a contact with the service providing machine without involvement of service provider(human) like ATMs, credit card readers at petrol pumps, online banking, money transfer through paytm or any other such app. In all the above mentioned examples degree of customer involvement is very high. Generally high contact process technology is more flexible to accommodate the unique needs of diverse cluster of customers.

## 2. LITERATURE SURVEY

**Cem Canel et al. (2000)** shows similarity and differences in services and manufacturing sectors. The study suggested various areas for improving performance in service sector and proves that various JIT techniques can also be implemented in service industry.

**Vikas Panchal et al. (2012)** identified various JIT elements in service sectors ( banking) which are mainly organization policy, team work, employee training, communication & information sharing, job satisfaction, employee feedback & suggestion, quality circles, technical supports, ergonomics design, customer satisfaction etc. It shows that implementation of JIT in banking increase value of bank by reducing inventory & communication gap.

**Vikas Panchal et al. (2013)** identified JIT elements that are important & easy to implement in the manufacturing industries & also presented the relative importance & difficulties in implementation of JIT elements in the banking sector and verified the data with the help of ANOVA techniques. According to the study the elements which are highly important & less difficult should be implemented first.

**Qasim ali nisar et al. (2014)** used simulation model for examine the benefits of JIT elements in financial sector, banking for loan approval process & found positive results. Banks can make their loan approval process efficient & effective by adopting cellular structure. The study was quantitative study for examining the role of JIT in banking sector.

**A.S.Aradhya et al. (2014)** studied various issues regarding implementation of JIT in a service industry. The study was conducted in the pilgrimage period and it was observed that waiting period of the pilgrims was reduced to 30 minutes from 8 hours by using JIT facility.

### Differences between manufacturing & service sector

- i. **Inseparability of production & consumption:** Since in manufacturing sector, products are first manufactured, inspected & then consumed, while in service sector there is simultaneous production & consumption. Customer has to be present during exercising of a service, and due to simultaneous production & consumption of service many opportunities for quality control are eliminated. Hence process control is more important in services than in manufacturing.
- ii **Intangibility:** While buying a product, a customer can see it, feel it and can assure himself / Oherself of its quality, while services often can't be seen & customer has to rely on the reputation of the service firm. Reputation of a firm depends on the reviews of the customers of a firm, which are not so reliable, because they differ from person to person.
- iii. **Perishability:** Service can't be stored. Empty airline seats, railway seats, hotel rooms, unfilled appointment of a doctor are all examples of opportunity losses. It sometimes also causes customer to wait or even sometimes customer is not served at all.
- iv. **Heterogeneity:** Since same service can be provided by different employees and also to different set of customers, so it varies from employee to employee & customer to customer, while in manufacturing products are mostly homogeneous.

It is clear from the above discussion that there are many differences between manufacturing and service industry. Competition in services has increased during the last few years due to faster communication and increased globalization. So there is a need to cut the cost of providing service without compromising quality of service by attacking waste (non- productive process). Waste is any process that does not add value to the product or service and can be removed by implementing JIT technique.

### JIT Concepts for service sector

JIT is not product oriented rather it is process oriented. So some of the concepts which are applicable in manufacturing can also be applied in service industries. These concepts are as following:

1. **Consistently High Quality:** Reputation of any company depends on consistent acceptable quality of its products or services. Defect free /Quality services contributes to be an important factor in the development of a service industry.
2. **Standard Work Method:** For highly repetitive service operations, efficiency can be effected by

analyzing work methods & standardization improvements for all employees to use.

3. **Close Supplier Ties:** Volume services such as restaurants like Dominos, Mcdonalds & Haldirams, online shopping sites like Amazon, Flipkart, Myntra & Bank ATMs require close supplier contacts to ensure frequent and uninterrupted supply, short lead time & high- quality shipments of supplier.
4. **Flexible Work Force:** In many service industries various task are not repetitive in nature, hence they require multitasking workforce which can carry out multiple tasks which do not require specific skill sets.
5. **Automation:** Now a days due to the advent of online transactions most of banking services, online reservation services in railways, airlines, hotels, movie theatre etc are required for 24 X 7. Hence automation of services is requirement of the day which will ensure hassle free uninterrupted services at the will and wish of consumer

### 3. JIT ISSUES IN SERVICE INDUSTRIES:

Service organizations are similar to manufacturing, as they both produce a product whether that product is a good or service. So JIT concepts are equally applicable to both sectors as they are process oriented and not product oriented. JIT approaches could be implemented in services in terms of reducing waiting time of the customer and generating a quick response to their demands.

### Integration of JIT Themes & Service Characteristics:

#### *Main themes of JIT are:*

1. Total visibility
2. Synchronization & Bbalance
3. Respect for People
4. Flexibility
5. Continuous Improvement
6. Sustainable Development & Responsibility for Environment
7. Simplicity
8. Holistic approach

### 4. METHODS FOR IMPROVING PERFORMANCE:

Performance of service organization can be improved by adopting following JIT methods:

#### **Training of Employees:**

Service employees include waiters in a restaurant, flight attendants, sales clerks, telephone operators & others who just facilitate with on time services.. Since they interact with the customers directly, hence they should be well

trained w.r.t hospitality skills, human behavior, etiquette & manners, fast response time, deal with unforeseen circumstances etc. Customers who are served by more trained employees are more satisfied, return more often & provide positive feedback about service.

#### **Technology:**

Service industries should use latest technologies to serve their customer and create awareness amongst them. As customer directly participate in some service process, the success of technological innovations will depend on customer acceptance like ATMs at banks, Paytm, online reservation for hotel, railway, airline etc.

#### **Layout:**

For effective implementation of JIT techniques, layout should be redesigned & some operations should merge. Service employees whose tasks are interrelated should be physically close to each other, so that they can share information in least possible time and ambiguity. Initially redesigning may cost the organization but it is an investment which is going to bring fortunes in long term.

#### **Quality:**

For better results quality should be embedded in the services right from the beginning phase. Employees should be well trained, so that they perform their task effectively and efficiently. The employee performance should be monitored regularly, and their ideas / suggestions of improving quality should be recorded, prioritized, interpreted, analyzed and implemented.

#### **Standardization:**

By standardization of job activities, workers training time the various associated costs can be reduced. Standardization in service is different from that of manufacturing - in manufacturing a product can be standardized fully, but in service sector one has to deal with human, and human behavior is not predictable & every customer has different likes and demands. So standardization should be done with a small degree of flexibility, so that customer with different needs can also be served with same set of resources.

### **5. REASONS FOR SLOW JIT IMPLEMENTATION IN SERVICE SECTOR:**

- i. Few years back competition was not huge in service sector.
- ii. Lack of information on JIT implementation.

- iii. Resistance from employees for change.
- iv. Departmental conflicts.
- v. Lots of investment is needed for JIT implementation.
- vi. Lack of training program.

To increase implementation rate, right strategy should be designed and adopted. Though redesigning of layout may be more expensive in short term, but in long term it will justify the investments. The organizations which are benefited by JIT implementation must set as an example to improve JIT implementation rate in service sector.

### **6. CONCLUSIONS**

The aim of this study is to examine the applicability of JIT in service sector. After successful implementation of JIT in manufacturing industry over years it can also be implemented in service industry, as JIT is process oriented not product oriented. In order to stay alive in this new competitive & dynamic market, waste should be minimized or ideally zeroed.. Traditional service system needed to be replaced by more flexible systems to meet new competitive challenges. In this paper, a comparison of manufacturing & service sector has been done to understand and learn that how service sector can be benefited by JIT implementation as many manufacturing industries have gained competitive advantages by JIT implementation.

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# Benefits and Barriers of Implementation of Lean Manufacturing in Indian SMEs

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**Abstract:** Lean Manufacturing (LM) is a production strategy for organizational effectiveness focusing on waste reduction and improving productivity through application of various tools. This paper gives an overview of the benefits and barriers in implementation of lean manufacturing in Indian SMEs (Small and medium sized enterprises) by comparing various aspects involved using statistics from different independent survey based research papers.

**Keywords:** Lean Manufacturing, Indian SMEs, waste reduction

## 1. INTRODUCTION

The term “value” in a manufacturing system is any action or process that a customer would be willing to pay for. Whereas, “waste” is any non-value adding activity in the system.

Lean manufacturing (LM) is a systematic approach to identify and eliminate the waste through continuous improvement and synchronizing the production process. LM is a multidimensional approach that encompasses a wide variety of management practices including just-in-time, total quality management (TQM), work teams, cellular manufacturing, supplier involvement, etc in an integrated system.

LM is based on the Toyota production system; the term “lean” has been used to characterize the Toyota paradigm. Lean describes a method of doing more with fewer people, equipment, space, etc while continually seeking to eliminate waste (MUDA). The goal is achievement of a perfectly leveled production system based on customer demand (TAKT time), and total elimination of all waste through continuous improvement (KAIZEN)

## 2. LEAN MANUFACTURING AND INDIAN INDUSTRIES

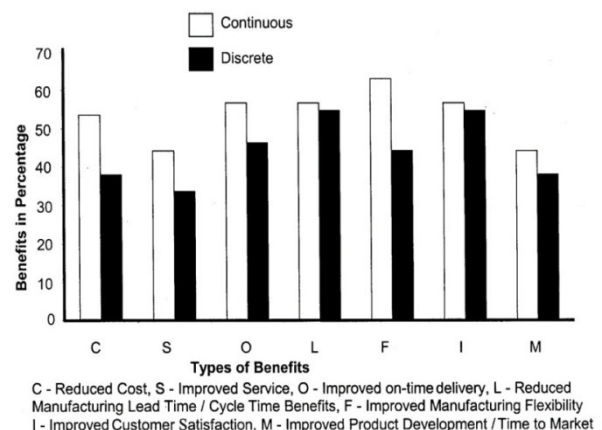
LM is not as simple to implement as it seems. It carries a lot of benefits which can help Indian SMEs to manufacture in accordance with global standards. But these benefits can only be realized if the implementation is right since misapplication of certain lean tools may result in additional wastage of resources and money. Proper analysis on the implementation and its benefits along with the challenges or barriers that limit.

the scope of LM in Indian SMEs are discussed :-

### A. Implementation and its benefits:-

Before understanding the direct advantages to be experienced, it is important to understand that Indian SMEs comprise many different kinds of waste like:-

- Overproduction: producing more product than required
- Inventory: Any supply in excess to produce product
- Waiting: Idle operator or machine time
- Motion: Movement of people or machine which does not add value
- Transportation: Any material movement that does not directly support value added operation
- Defects: Making defective parts
- Extra processing: Any process that does not add value to product



**Fig. 1. Benefits in different operational areas by application of lean manufacturing.**



The survey (reference: Mahapatra, S. S., and S. R. Mohanty. "Lean manufacturing in continuous process industry: an empirical study." (2007) )benefits in percentage of implementation of lean manufacturing in both continuous and discrete manufacturing systems.

To achieve this, various lean tools have been proposed for effective utilization of resources. Although, tools are generic in nature, application of a selected bundle of tools and their sequence must be considered judiciously in a specific situation depending on external and internal operating conditions.

These tools include:-

- TAKT time: TAKT is the rate at which the customer requires the product and is computed as  $\text{TAKT time} = \frac{\text{Available work time}}{\text{Customer demand}}$  per day.
- Standardized work: Jobs are broken down into elements and examined to determine best and safest method for each.
- Workplace organization (5S concept): Sort (Seiri), Set-in-Order (Seiton), Shine (Seisco), Standardize (Shitsuke), Sustain (Seiketsu).
- Visual factory: Information is made available and understandable at a glance.
- Point-of-use-storage (POUS): Locate all parts, raw materials, tools and fixtures as close as possible.
- Quality at source: Error proofing devices are used for example Pokayoke
- Teams: Departmental barriers are eliminated and replaced with cross-functional teams.
- Kanban: An information system that controls (Pulls) required parts in required quantities at the required time.
- Kaizen: Japanese word for continuous improvement
- Quick changeover/single minute exchange of dies (SMED): A system that allows the mixing of production without slowing output or creating higher costs from waste setup.
- One piece flow: To minimize work in process, operators focus on completing one part through the operation before starting next part.
- Cells: Proper placement of machines
- Total productive maintenance (TPM): Consists of a company wide equipment maintenance program that covers the equipment life cycle and requires participation by every employee.

- Value stream mapping (VSM): VSM is a method of visually mapping a product's production path, including materials and information flow, from dock to stock. It takes a holistic look at the activity required (both value added and non-value added) to move a product from raw material to customer.

### ***B. Barriers in implementation:***

There exist various different types of issues in implementation of LM. A classification considering all the intrinsic as well as extrinsic factors in an Indian SME ecosystem is stated below. This classification is placed in the order as shown according to their importance as studied by the survey of 127 industries (reference: Singh, Bhim, S. K. Garg, and S. K. Sharma. "Scope for lean implementation: a survey of 127 Indian industries." )

1. Market issues
  - Stiff competition
  - Low sales revenue
  - Poor brand image
2. Customers issues
  - To reduce response time
  - To deliver in small lots
  - To implement self-certification
  - To reduce rejection
  - To increase range of products
3. Supplier issues
  - Unreliable transport
  - Frequent changes in supply schedule
  - Poor communication system
  - Poor vendor response
  - Frequent design changes
  - High lead time
4. Organizational issues
  - Frequent breakdown
  - High inventory
  - High rejection rate
  - Underutilization of capacity
  - Workers absenteeism
  - Obsolete technology
  - High setup time/changeover time
5. Top management issues
  - Lack of funds
  - Lack of multi-skilled manpower
  - Lack of quality consciousness
  - Lack of support from top management

Market issue appears to be the most dominating issue which indicates that there are sufficient number of competitors in the Indian market. This also shows the stiff competition due to which the sale revenue made by companies is low. Also, this makes it harder for firms to make a good brand image as the market is very dynamic. Second, main issue is customer issues, which reflects the high customer expectation which requires the companies to push their limits with all their services and products. This is because the customers expect high quality and wide range of custom made products to be delivered in less time. Moreover, variable demand makes it even tougher for companies to meet all the customer expectations. Next in the series is organizational issue. This basically comprises of all the organizational short-comings due to which it is hard to attain the principles of lean manufacturing. These include frequent breakdowns, obsolete technology, worker absenteeism, high setup time, underutilization of capacity, and high rejection rate. The primary reason for these issues is lack of awareness and low priority to implement the basic principles of production engineering. The last in the series of importance is top management issue. It includes the lack of funds, multi-skilled manpower, quality consciousness and support from top management. The primary reason behind these issues is first the lack of resources and funding to indian SMEs mainly because of their smaller size which makes them incapable to work on the above mentioned issues.

These factors together with a lack of attitude and desire in implementation of lean principles make it harder to achieve lean manufacturing in India.

#### **C. Other Factors for low priority to lean implementation:**

- The major reason for low priority to lean practices is related to human behavior. The difficulty in changing the mindset of people may be because of the fear of losing jobs, perception of additional work loads, and additional burden in reduction of existing process time by elimination of non-value added activities. These mindsets arise due to various reasons like failure of company management to communicate efficiently with lower order workers, incapability of the already present workforce to adapt to new changes in technology, and lack of dedication required to practice lean manufacturing principles.
- Other important factors in low priority to lean practices include inadequate lean training opportunities, more time required to implement lean concepts, too general procedures and not industry-specific procedures, and less lean awareness programs in India.
- In addition to above reasons, high consultancy fee and initial high investment are perceived to be the obstacles to successful implementation of lean practices. These are related to “cost factors”. Therefore, to get the ample

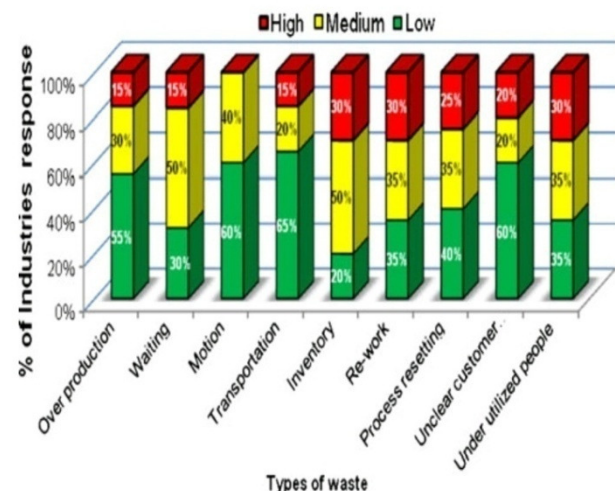
support from the management, it needs a detailed cost-benefit analysis. Such analysis are hard to carry in Indian SMEs ecosystem since they are very unorganized and also because they lack the funds and resources for the same.

#### **D. Prevailing status of lean wastes in implemented industries:**

Another area worth exploring is awareness about waste prevailing in organizations that have already implemented lean practices. The fig shows the response of a survey of lean practices in Indian machine tool industries (reference: Eswaramoorthi, M., et al. "A survey on lean practices in Indian machine tool industries." ).

It highlights the waste level in three categories that are low, medium and high. It was found that major waste indicated as medium level are inventory, waiting, motion, re-work, process resetting, and underutilized skills of employees. These results indicate the factors discussed earlier like lower volume of demand and fluctuation in customer orders, might have influence on waste generation. Since the varieties are high, possibilities of committing mistakes are also high as working with different products every time leads to more incoherence. The shop floor employees learn lessons from previous defects and failures and use them for defect prevention in case of repeated orders. So, it can be concluded that the variety change, frequent design changes, and customer influence on manufacturing process play a significant role in waste generation.

The other waste like inventory and waiting are the consequences of re-work and process resetting. Further, the low volume of demand may be the reason for using skilled people to other work, which leads to predominantly stated waste in the form of untapped human skills.



**Fig: 2. Prevailing status of lean wastes**

### 3. CONCLUSION

The paper presented a significant insight into different factors involved in the importance and implementation of lean manufacturing practices in Indian SMEs. This was done by reviewing, accessing and compiling the survey studies done by independent organizations and individuals in the given field.

India is a major manufacturing hub and for its sustainable growth it is important for the Indian SMEs which make the backbone of Indian manufacturing strength to adapt to new technologies and practices so that they can compete and adhere to global manufacturing requirements. LM was implemented in other major global manufacturing hubs decades ago and it has shown promising results.

Also, the above studies show that the scope in development of lean manufacturing practices in India is huge and is attainable. It certainly carries a lot of benefits but is also hard to implement and sustain. There needs special attention from the government as well the industry owners and employees since the above mentioned benefits can be achieved only by transforming the employees as lean thinkers, and suitable training and awareness programs are appropriate solutions.

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# Literature Review on Six Sigma Quality Improvement Methodology

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**Abstract:** In the current era of globalization, customer is supreme and purchase products from anywhere, hence focus should be enchantment of the customer rather than satisfaction. The customer is not liable to pay for any rejection, rework or non-value added activity. Six sigma methodology works on principles of customer converging, process oriented, process data driven and breakthrough improvement strategy. Every day new success story reflects the strength of it, but on the other hand, many projects also fail due to lack in implementation. Author here, present a brief literature survey regarding each phase of DMAIC methodology, latest trend of integration two powerful methodologies Lean and Six sigma as well Critical Success Factors for effective implementation of Six Sigma methodology and found that Lean and six sigma both focuses on concept of continuous improvement and also impact of management leadership & commitment and linking six sigma with the business and customer needs are the most significant among all success factor.

**Keywords:** DMAIC, Six Sigma, CSF, Lean six sigma.

## 1. INTRODUCTION

Six sigma methodology was developed by Bill smith at Motorola Corporation. Later other market giants like Allied signals, Sony, General Electric, Citi bank etc also adopted this six sigma and gain quantum jump. It just not provide quality assurance (QA) but also provide quality control (QC) function. It is systematic and organized methodology for existing as well as new product, process and service improvement.

**TABLE 1: DPMO level and sigma level relation**

Sigma level	Percentage output	Defects per million opportunities (DPMO)
1 $\sigma$	30.23	697700
2 $\sigma$	69.13	308700
3 $\sigma$	93.32	66810
4 $\sigma$	99.3790	6210
5 $\sigma$	99.976700	233
6 $\sigma$	99.9996600	3.4

The main aim of six sigma methodology is to reduce variation among products or processes through continuous improvement process, it identifies potential root causes for variation and eliminate them by using DMAIC (Define, Measure, Analyze, Improvement, Control) or DMADV (Define, Measure, Analyze, Design, Verify) methodology.

Statistical meaning of “ $\sigma$ ” represents variation, it indicates in term of how many sigma shifts that can be placed within

upper and lower control limit, higher the sigma (variation) value indicated less sigma's can be placed between control limit and for lower value of sigma more number of sigma can be placed between control limits. Hence six sigma is better compare to that of three sigma level. In table 1 author mentioned sigma level and related defects per million.

## 2. METHODOLOGY

Adoption of six sigma required to go through DMAIC (when product is actually existing and quality improvement is required) and DMADV (when newly developed product is required to improved quality) approaches. Form various literatures and researches we came to know some basic fundamentals of both he approaches.

**2.1 Define-**Identification of most significant problem. It is a creation of Vision and Mission for the project by linking six sigma project with a business case.

In Six sigma methodology each phase provides input for the next level.

A selected problem should have a strategic impact on the firm's performance, also it should correlate business goals of organization as well interlink the same with the customer satisfaction.

A project selection for six sigma have a strategic orientation as management commitment is critical for project success.

For selection of six sigma project essential to involve Quality function deployment technique, which in turn will help to identify unspoken needs of customers which are vague and convert qualitative information into quantitative.

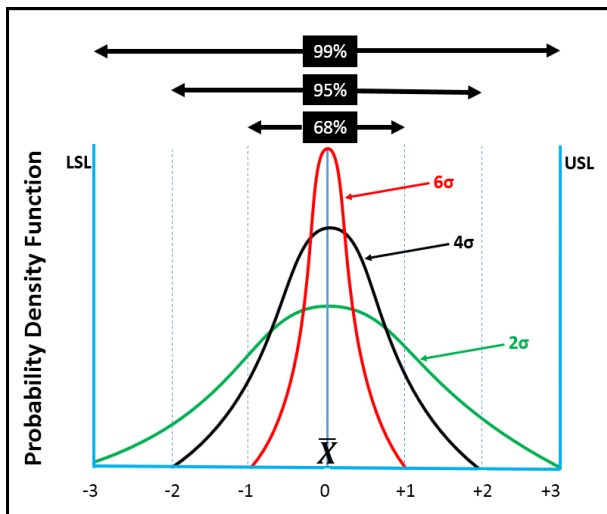
QFD also identify the technical capability of firms to produce a product or service as per required standards of customer and identifies which alterations with respect to technology and process are essential to meet the demand. (Shanmugaraja, 2012)

Another approach for project selection is based on FMEA (Failure mode effect Analysis), works on Risk Priority Number, which recognize, evaluate potential failure and also end effect and give opportunity to eliminate the chance of failure. (Kirkire, 2015) (Su, 2008)

However, in latest trend a project selection should be on the basis of Fuzzy logical system or analytical Process Network (ANP) or should require weighted basis criteria for problem selection will cover all aspects of criticality. (Shanmugaraja, 2012)

Define phase is most critical, hence more time and effort are essential to invest for problem criticality. Team formation is essential to constitutes of MBB and BB for optimum handling of problems and this team in turn will identify potential gains and allocate resources for solutions.

**2.2 Measure:** Nothing can be improved until it is measured. Measurement system will provide a baseline for improvement, also identifies the significance level of criticality pertaining to problem selected. However, timely availability of qualitative data is the main objective of this phase. This phase involves identification of the characteristics of the data to be collected, validation of accuracy of measurement system (Gijo, 2014)



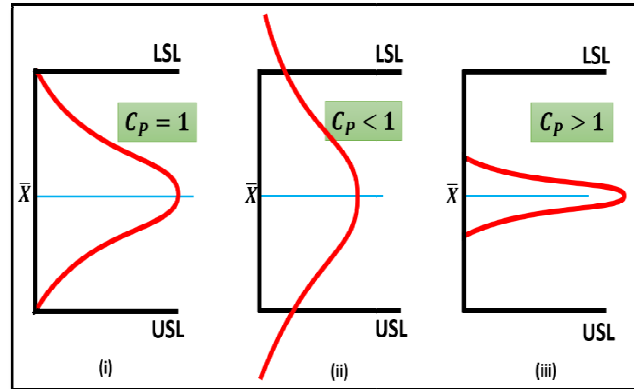
**Fig. 1 Variation in process and Sigma level normal distribution curve**

As an output of this phase will clearly state process sigma level. Based on type of data, for discrete data DPMO (defects per million opportunities) are calculated, and for continuous data  $C_p$  and  $C_{pk}$  index are vital.

$$DPMO = \frac{\text{Number of defects identified} \times 10^6}{\text{Number of Opportunities} \times \text{total inspected units}}$$

$C_p$  measure indicates the spread of the process, with respect to the normal distribution of curve, which is dependent upon the specification limit and the variance of Process.

$$C_p = \frac{USL - LSL}{6 \times \sigma}$$



**Fig. 2. Cp index and Variation in Process**

$C_{pk}$  index measures the position of mean with respect to two control limits of the process.

$$C_{pk} = \text{Minimum} \left[ \frac{USL - \bar{X}}{3 \times \sigma} - \frac{\bar{X} - LSL}{3 \times \sigma} \right]$$

Ideally both the values of  $C_p$  and  $C_{pk}$  should be equal and higher than 1.

**TABLE 2. Types of measure and relationship with what to measure.**

Type of Measure	What to measure?
Supplier's effectiveness	Resources input (material lead time, specific item delivery etc.)
Firm's efficiency	Process (Cycle time, productivity, Rejection rate etc.)
Firm's effectiveness	Output of firm (How well meeting customer requirements)

**2.3 Analyze** - Identification of root causes liable for variation.

At this stage Course of action is prepared to close the gap between how things currently work and how they should work to meet improvement goals, Identifies root causes of the problem and validate same. At the end most affecting root causes are selected for improvements.

It is the most critical step which defines due to lack of several inputs the key objective is not achieved.

It mainly involves open root cause analysis (Ishikawa diagram) and refined them by close root cause analysis (5-why Analysis). (Thomas, 2006)

A Common mistake made by six sigma team at this phase is rushing from an initial problem to set of preconceived solutions.

**2.4 Improve:** Improvement in existing process to meet targeted results.

Most favorable root causes documented in previous stage are input for this phase and provide basis for improvement direction.

At this stage major focus is avail to make the process more robust lead to work even in presence of noise factor which are out of control factors for variation. It is done by setting process parameters at optimum level which are constructed using Design of Experiment and Taguchi Techniques. (Bañuelas, 2005)

**2.5 Control:** Sustain Developed process.

Main objective of this phase is to keep in control process by mistake proofing. If process goes out of control it quickly detects it and identify causes and maintain same in control level. Here mainly role of statistical quality control (SQC) plays a vital role to check online process stability. (Gijo, 2011)

### 3. LATEST INNOVATIONS IN SIX SIGMA

Latest trend in the field of quality engineering is the mixture of two powerful methodologies lean and six sigma to enhance performance. Lean manufacturing focuses on elimination of non-value added activity from the core system where six sigma with variation. Lean is primarily focuses on exchange of information and materials between the process steps whereas Six Sigma is concentrating on addressing poorly performing value adding transformations within the process. As lean is bottom-up approach and six sigma is vice versa hybrid methodology involve all aspect of involvement including top and bottom level employees. (Antony, 2011)

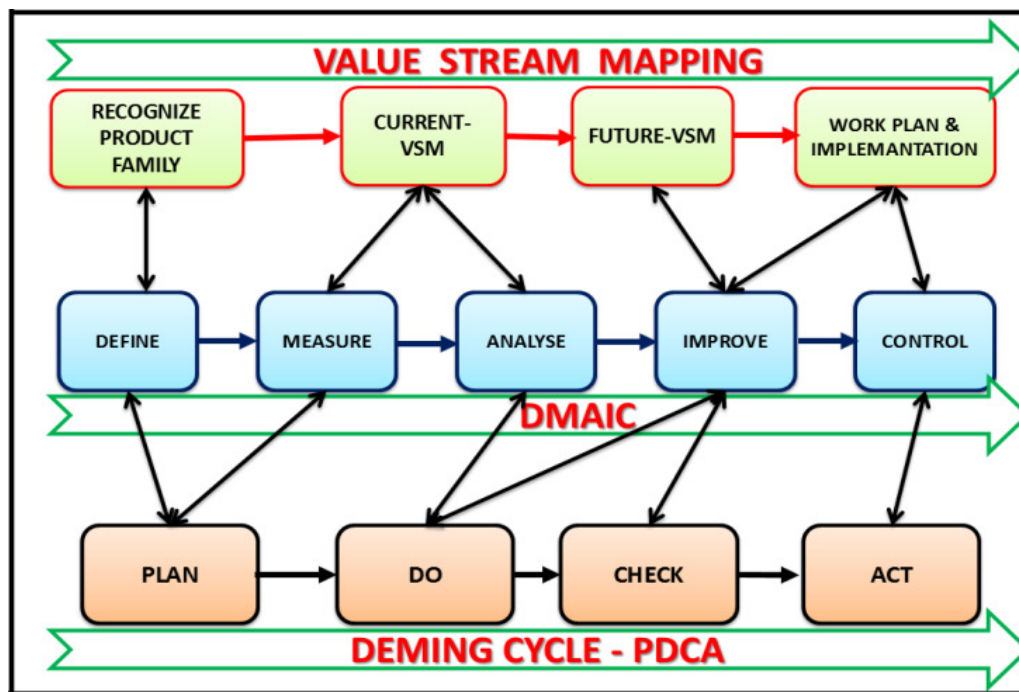


Fig. 3. Latest trend of Lean-Sigma

Lean Manufacturing focuses on elimination of various losses associated with production system such as waiting time, overproduction, rework/rejection, unnecessary motion, over processing, excess inventory, unnecessary transport which are called as MUDA, which evolve from Toyota Production System.

Organizations successfully achieved control over Muda, Mura and Muri have set a benchmark of world class manufacturing facility.

Lean Manufacturing indicates the speed of working and six sigma indicates reduction in variation of that process.

However different Methodologies and bodies exist in the field of quality revolution like Lean, TQM, ISO, Six sigma. The crux of all these remain same that is overall improvement of organization by eliminating non-value added activity. (Anderson, 2006)

From figure(3) it is clear from comparison of Value stream mapping, Six sigma and PDCA cycle drive a clear conclusion that is identify problem, evaluate magnitude,

develop key alternative or improvement within the process and implement the same.

In contrast with TQM and Six sigma, Six Sigma is based on a preplanned project charter which details about the scale of a project, financial targets, and anticipated monetary benefits. In comparison, organizations that have implemented TQM, work without knowing what the financial gains might be. (Antony, 2009)

**TABLE 3: Critical Success Factors for Six Sigma implementation**

<b>CRITICALSUCCESSFACTORS</b>	<b>Desai at al.2012</b>	<b>E.V.Jijo at al. 2014</b>	<b>T.V.Rao at al. 2005</b>	<b>Ricardo Banuelo et al. 2005</b>	<b>Jiju Antony et al. 2012</b>	<b>A. Thomas et al. 2008</b>	<b>SajaAlbiwi, 2013</b>	<b>R. Hilton, 2012</b>	<b>M. Shannugaraj et at. 2012</b>	<b>Chao –Ton -2008</b>
Management commitment	√	√		√			√	√	√	√
Linking six sigma with business goals and customer needs	√	√		√		√	√		√	√
Right Infrastructure of MBBs, BBs, GBs.	√	√					√		√	√
Initiation of Many quality Projects together			√							
Cultural change/Change Management	√						√	√	√	
Training of Employees/ Team Work	√			√			√	√	√	
Understanding of DMAIC Methodology	√					√		√	√	
Project Management Skills	√						√	√	√	
Project Prioritization	√				√		√		√	√
Leadership	√				√		√	√	√	
Project Progress Monitoring				√			√	√	√	
Definition of CTQ's					√					
Statistical Training					√	√		√		
Communication									√	
Accounting and Rewarding									√	
Sustaining Results					√				√	
Information system and Data Measurement								√	√	

#### 4. CONCLUSION

This paper was an attempt to understand concept of DMAIC methodology studied by various researchers and illustration of methodology in detail for learning purpose.

The six sigma methodology of process improvement is process data driven, customer centric and process oriented methodology which focuses on elimination of causes producing variation. Moreover in recent trend it is most powerful methodology for breakthrough quality

improvement through effective use of statistical and non-statistical tools. However it is focusing only on trivial few root causes elimination however variation is also contributed by vital many root causes. Also implementation hurdles, barriers and level of knowledge of concern person handling project differs in SME and large scale industries. Also lack of specific governing body for allocation of training and certification makes differs in knowledge of MBB'S and GB's.

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# Cost of Quality Measurement and Analysis

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**Abstract:** The high competitiveness makes the search production cost reduction a constant in working place, but it is necessary to reduce costs without compromising quality. When a product is in the manufacturing and this has to be scraped, we have more cost than the raw material used, it is important to consider the man power and operations, continues quality improvement is a key factor in the strategy for competitiveness. Quality cost is one tool among many other that can help in continues quality improvement properly applying quality cost techniques is critical to the efforts. Initially, a complete quality study could provide awarress and guideline to steering the team and guide the project. In this paper “Cost Of Quality” analysis has been done using different techniques.

**Keywords:** Cost of poor Quality, SWOT analysis, Six Sigma

## 1. INTRODUCTION

Cost of quality (COQ) is now a well-known concept for many years. Dr. Joseph Juan initiate the concept of cost of quality in 1951 and American society for quality established a quality cost committed in supervisor of quality management division in 1961. But the main credit of popular concept goes to Philip B Crosby who highlight COQ in his book “Quality is free”. Now most famous quality standers like ISO 9000, AS 9000 and QS 9000 recommended the implementation of COQ model for improvement of product and service quality. COQ is always remained a confusion concept. It has never been clear that COQ is whether the cost to insure quality or extra cost to be paid in case of poor quality.

Most of the time, poor quality cost just to referred both the conformance and non- conformance cost which included prevention and appraisal cost and internal and external failure costs, respectively. But in addition to these two types of costs, this are hidden cost that are generally neglected in modeling COQ method are these include cost due to customer incurred, reputation loss dissatisfaction of customers.

An organization’s mainly survive and maintain high quality goods or service with a comprehensive understanding of

cost related to quality this goods or services with the comprehensive understanding of the cost related to quality this goal can be achieved. Many companies in the world are now gradually promoting quality as the center customer value and regard it is as a key concept of company strategy in order to achieve the company strategy in order to achieve the competitive edge. Costs are defined as the summation of cost over the life of products.

The present study makes the case that quality efforts in translation are indispensable and worth paying for, as these costs actually save money in the long run.

One of the well known approaches to reduce cost of poor quality in a project based on six sigma DMAIC methodologies is used to improve already existing processes and had been proven to be successful in reducing cost, improving cycle time, eliminate defects, raising customer satisfaction, and significantly increase profitability in every industries and organizations.

## 2. LITERATURE REVIEW OF THE CQMA

Before taking up the case explanation, Let us briefly review the studies that have shows successful cases of COQ and Six Sigma DMAIC methodology application for reduce poor cost of qualities.

**TABLE I: Summary of literature review and experts Opinion**

Main criteria	Enablers adoption in SC (Sub Criteria)	References
Cost of good quality	These cost associated with preventing defects and appraising defects.	Cost of poor quality analysis for automobile industry case study by S.N Telic, V.S. Magalia
Cost of poor quality	These include all the failure cost associated with a products	Cost of Quality : hidden costs by Suresh Kumar Krishnan, Arawait Agus & Nooreha Husain.
System	Steps for system engineering devlopments.	Muhammad Arsalan Farooq*, a, Randolph

Main criteria		Enablers adoption in SC (Sub Criteria)	References
engineering methodology			Kirchaina, Henriqueta Novoab and Antonio Araujob “Cost of Quality: Evaluating Cost-Quality Trade-Offs for Inspection Strategies of Manufacturing Processes”
Steps in Implementing Quality Costs		Steps for applying COQ in industries	Hassan Ali, Vajiha Arif, Danial Saeed, Ahsan ali khan “Classical model base analysis of costing of poor quality in manufacturing organization.”
methodology		Methodology is observation of deriving process components.	Hassan Ali, Vajiha Arif, Danial Saeed, Ahsan ali khan “Classical model base analysis of costing of poor quality in manufacturing organization.”
Measurement of prevention and appraisal cost		Define different costs	Georgios giakatis

### 3. THE MAIN TYPES AND DESCRIPTION OF COST OF QUALITY

#### 3.1 Cost Of Good Quality

**Prevention Costs:** These costs are associated with preventing defects and imperfection from occurring. the focus of a prevention cost is to assure quality and minimize or avoided the likelihood of an event with an adverse impact on the company goods, services and daily operations.

Examples: new products review, quality planning's, supplier capability service, process capability evaluations, quality improvements team meetings, quality improvement projects, quality educations and trainings.

**Appraisal Costs:** these costs are direct costs of measuring quality. In this case, quality is defending as the conformance to customer expectation .this includes: lab testing, inspection, test equipment and material.

Example: expenses from inspection, calibration costs, products/process audits etc...

#### 3.2 Cost of Poor Quality

**Internal Failure Cost:** failure costs occurring prior to deliver or shipment of the production or the furnishing of a service to the customer.

Example: Scrap, rework, re-inspection, retesting, material review etc...

**External Failure Costs:** Failure costs occurring after delivery or shipment of the products and during or after furnishing of service to the customers.

Examples: Processing customer complaints, returns, warranty claims, products recall.

### 4. STEPS IN IMPLEMENTING QUALITY COSTS

1. Review the literature on quality costs or consult other in similar industry that is using the same tools. 2. Select one organization unit of company to serve as a pilot site. 3. Discuss the objective of study with the key people in the organization. 4. Collect cost data from object that convenient available from the accounting systems 5. Make a purpose for management to study full situations. 6. Published draft of categories defining the cost of poor quality. 7. Finalize the definition and secure management approval. 8. Secure the arrangement on responsibility for data collection and report presentation. 9. Collect and summaries the data. 10. Presnt the cost results and analyzes the way to eliminate the cost of poor quality.

### 5. METHODOLOGY

The methodology is based on the observation of manufacturing processed then obtains analysis with help of PAF cost analysis and SWOT analysis. Then a quality cost model is proposed for implementation in manufacturing.

#### 5.1 SWOT Analysis

First, decide how you will use the SWOT analysis. Use this type of analysis to evaluate employees, business models, projects or companies. It may also be used on a personal level to improve performance at work or other areas of your life. Prepare a chart of four sections by dividing the paper in half both horizontally and vertically. Label each section: Strengths, Weaknesses, Opportunities and Threats.

#### 1. Strengths

Consider and list your strengths on the chart. If this is a personal analysis, this would include things such as education, experience and character traits that give you an edge over others. If you are doing a business analysis this

would include things such as patents, capital, accreditation or other recognition and reputation.

## 2. Weaknesses

Next consider your weaknesses. On a personal level this may include gaps in experience or education and poor work habits such as lateness. On a business analysis this includes factors such as financial problems, poor morale or a small, unprofitable customer base.

## 3. Opportunities

Consider what opportunities are available or coming up. For a personal analysis this may include training opportunities or a new job or promotion. Business opportunities may include access to new technology, new regulations opening up global trade or trends moving customers toward your business.

## 4. Threats

Record any threats or things working against you or your business. Personal threats may include outsourcing or technology threatening your job or a personal medical condition or family situation preventing you from reaching

work and personal goals. Threats to businesses include things such as a new competitor, losing a supplier or new or changing laws that may negatively impact your business.

## 5.2 PAF Costing and analysis

PAF analysis based on the prevention, appraisal and failure cause analysis.

## 5.3 Define goal of quality model

The goal is proposed quality cost model main purpose is reducing internal and external failure costs. It mean this model eliminate or minimize the failure costs.

## 5.4 Make actual cost breakdown structure

The total cost can be divided into seven different types of costs including labor costs, equipment cost, material costs, overheads costs, risk costs cost of subsidiaries, and risk cost and profit costs.

## Measuring Prevention /appraisal costs

Following procedure is adopting for measuring prevention/appraisal costs

**TABLE 1: Planned/ Actual Production vs. time in days**

Day	Production		Activity 1		Activity 2	
	Planned	Actual	Planned	Actual	Planned	actual
1						
2						
3						
total	Total P	Total A				
Loss factor= $1 - ( \frac{\text{Total A}}{\text{Total P}} ) * 100$						

**TABLE 2: cost value of production week**

factor	Actual	Planned	Difference	Reason
Production	Total A	Total P	total P- total A	
Price/unit	P			
Weekly Income	Total A * P	Total P * P	(total P- total A) * P	
Loss factors = $(\frac{\text{total P} - \text{total A}}{\text{Total A}}) * 100$				

**TABLE 3: weekly COPQ**

Item	Loss	Factor	% loss	remark
Labor cost				
Equipment Cost				
Quality Cost				
Material Cost				
Total loss going week:-				
Modified Loss Per Week = loss factors * actual cost per week				

## 6. SYSTEMS ENGINEERING METHODOLOGY

The ten steps of system engineering methodology are

1. Define clearly the project scope, problem to be analyzed and identify the team;
2. Develop a complete process mapping and identify the quality control points relevant to the problem identified;
3. Identification of all elements along the production line of a product and collection of all relations between them;
4. Transfer all data to a Design Structure Matrix (DSM), parsed by manufacturing process;
5. Apply mathematical operations to DSM and evaluate and characterize the final DSM;
6. Use the most adequate quality improvement tools to further refine the critical quality characteristics and areas previously identified;
7. Improve the manufacturing process according to the results;
8. Perform cost of quality analysis to enable an informed choice;
9. Evaluate again the relations of elements, deleting the elements that were eliminated and update the DSM;
10. Standardize the results and refine the model over time.

## 7. METHODS AND EFFECT OF SIX SIGMA WHAT THE RELATION BETWEEN THE "COST OF GOOD QUALITY" AND THE "COST OF POOR QUALITY"?

The traditional view would be to consider that if a company wants to reduce defects and by the reduce the cost of poor quality, the cost of good quality would have to be increased, meaning higher investments in any kind of checking, testing, evaluation, training of operators, training of supervisor . The Six Sigma philosophy however, of building quality into process, service and products and doing things right the first time, the increase of the "cost of good quality", while striving for zero defect performance, can be smoothed if processes get better.

## 8. CONCLUSION

When the Cost of achieving good Quality increases; cost of poor Quality reduces automatically. We getting benefits like as, Quantity of size of defect are reducing, identify major problems. - Measure the results of quality

improvement activities. - Align Quality goal with organization goals. - Set cost reduction targets - Identify unnecessary costs and efforts and derive cost for repairs. Analysis of four quarter also shown a consideration trend of reduce of COQ in each successive department .its installing and using quality cost system will allow leadership to make guide translation from an organization current opportunity cost reduce or minimize.

## Applications

Its use for

- Project Descriptions
- Data collecting
- Data analysis
- Result analysis
- Benchmarking the products
- Trend analysis

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# Shainin Tool Approach for Quality Monitoring in Injection Moulding

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**Abstract:** This study deals with Shainin Design of Experiments method, that was employed for flaw detection and quality monitoring in injection moulding process. Injection moulded manufactured products are often susceptible to many moulding defects. Thus, in order to reduce various defects, appropriate analysis of the root cause has to be done, so that actual reasons behind the occurrence of the defects could be found out and corrective actions undertaken. Trouble shooting in injection moulding of a cosmetic gadget in EPDM has been attempted in this study using shainin tools like, Product process search and Variable search. This has resulted in identifying and analysing the source of variation eliminating the insignificant factors responsible for the defects. Incorporating corrective actions and validating the improvements has been achieved through B vs C analysis. The investigation yielded in drastic reduction of defective parts from 12% to 4%. There is ample scope for exploring further into the process and achieve promising results.

**Keywords:** shainin tool, injection moulding, variable search, B vs C analysis

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## 1. INTRODUCTION

Injection moulding is a manufacturing process, which is widely employed for producing a wide variety of commodity and engineering components mostly from thermoplastics polymers. This process is very complex and it demands close monitoring of number of process parameters, in order to relish articles of acceptable quality levels. This study pertains to quality monitoring of the barrels for a cosmetic gadget made from EPDM by injection moulding technique. Shainin Design of Experiments (SS) approach is employed in the study as a quality monitoring tool in identifying the most significant process parameters that influence the product quality.

## 2. LITERATURE REVIEW

Shainin tool as a Design of Experiments methodology and approach has been advocating, “Don’t let the engineers do the guessing; let the parts do the talking. Andrew Thomas et. al. (2004) illustrated how shainin variable search method has been used in identifying the influencing variables that control the joint strength of honeycomb composite tongue and slot joints within an aerospace company. Nagaraja Reddy K M et. al. (2014) mentioned that, Bosch production system (BPS) has successfully implemented 'shainin tool for the root cause identification as a DOE technique for analysis of a quality related problem. Tirthankar Dasgupta, Nagesh Adigz and C. F. Jeff Wu (2010) carried out an in-depth analysis of Dorian Shainin's variable search (VS) method and the conditions under which the VS approach does and does not work well in

comparison to traditional designs were identified. The crucial roles of process knowledge and noise variation in successful application of the VS design are established through theoretical and simulation studies.

## 3. METHODOLOGY

Shainin technique consists of a collection of principles, which make up the framework of a continually evolving approach to quality. These techniques help to identify key factors and to subsequently adjust these factors in order to achieve sustainable performance improvements.

## 4. EMPIRICAL STUDY

In this section, the empirical study conducted is presented to illustrate the application of the Shainin method in quality monitoring of an injection moulding process.

### 4.1 Problem Description

The production data relating to the process parameters of the injection moulding process in the manufacturing firm were recorded and analyzed to detect the defect causing the highest percentage rejection in the entire production run. It was identified that the highest percentage rejections were due to the variation in length of the product. Hence, the length of the product was taken as the output variable (Green Y). The objective of the method was to identify and/or confirm the most influential parameters causing variation in length of the product. The potential suspected sources of variation were the injection process parameters and those that were decided to be investigated were barrel temperature, nozzle temperature, injection pressure,

injection speed, injection time, hold time, hold speed, hold pressure and cooling time.

#### 4.2 Problem Description

Shainin method's product process search tool is a clue generation tool used to identify the important factors relating to the defect. In this tool, Six pairs of Best of Best (BOB) and Worst of Worst (WOW) products and their parameter settings were noted down. Tukey test was applied to determine the important parameters.

#### 4.3 Application of the Shainin Method

Table I shows product process search method result. The inference obtained from the table I- product process search is that the injection pressure, time, hold speed, hold pressure and hold time were the significant factors causing variation and thus leading to the defect.

After product process search, the second Shainin tool used was variable search (VS). The factors causing the defect and the levels of these factors were listed and ordered according to their importance shown in the Table II. To find out whether the parameters and the levels identified were correct or not, 3 random observations were taken from the all factors kept at their (+) levels and vice versa. All these 6 experiments were done in a random manner. Table III shows the measurements obtained from the six experiments.

The difference between mean ( $\bar{D}_m$ ) and the average range ( $\bar{R}$ ) were worked out; and the  $\bar{D}_m/\bar{R}$  ratio (determination ratio) was checked to find out whether the important factors are inside the determined list as shown in Table IV. Since  $\bar{D}_m / \bar{R} = 4.788 (\geq 1.25)$ , the factors have been identified correctly, and this list contains the critical factors inside.

After this stage, the "Control Limits"(CL) for the median was calculated.

$$CL(\text{best}) = 7.933 \pm 2.776(0.055/1.81) = (7.849-8.018)$$

$$CL(\text{worst}) = 7.670 \pm 2.776(0.055/1.81) = (7.586-7.754)$$

Experiments were done, while one factor was kept at (+) level and all other factors were kept at their (-) levels and vice versa to find an important factors. For the main experimentation, as shown in table V, factors were listed in order of importance and that was taken individually.

Capping run experiment was done for the three important factors. According to the results, as the new response values were inside the control limits, these three factors and/or interaction were confirmed for their impact on the process (Capping Run is successful).

**TABLE I: Product search method result**

Selection of WOW and BOB products based on length (cm)		Comparison of product and process features associated with Worst of Worst (W) and Best of Best(B) products									
		SIGNIFICANT INPUT PARAMETERS									
		INJECTION PRESSURE		INJECTION TIME(sec)		HOLD SPEED(% of barrel length)		HOLD PRESSURE(bar)		HOLD TIME(sec)	
B1	7.93	B2	60	B2	1.3	B1	8	W1	10	B1	3
B1	7.93	B3	60	B3	1.3	B2	8	W2	10	B2	3
B3	7.93	B4	60	B4	1.3	B3	8	W3	15	B3	3
B4	7.93	B5	60	B5	1.3	B4	8	W4	25	B4	3
B5	7.93	B6	60	W5	1.3	B5	8	W5	25	B5	3
B6	7.95	W5	60	W1	1.36	B6	8	W6	25	B6	3
W1	7.20	W6	60	W6	1.5	W3	8	B3	27	W3	3
W1	6.03	B1	80	W2	2	W4	8	B1	28	W1	4
W3	7.84	W1	80	B1	2.1	W5	8	B2	30	W2	4
W4	7.68	W2	90	B6	2.1	W1	10	B4	30	W5	4
W5	7.24	W3	90	W3	2.1	W2	10	B5	30	W6	4
W6	7.84	W4	90	W4	2.1	W6	10	B6	30	W4	5
TUKEY END COUNT OF EACH PARAMETER	TOP	5	TOP	4	TOP	6	TOP	6	TOP	6	
	BTM	4	BTM	2	BTM	6	BTM	6	BTM	6	
	TOTAL	9	TOTAL	6	TOTAL	12	TOTAL	12	TOTAL	12	

**TABLE II: List of factors according to their importance**

Labels	Factors	+ Settings	- Settings
A	Injection Speed (%)	99.9	60
B	Injection Pressure (bar)	60	80
C	Hold Speed (%)	8	10
D	Hold Pressure (bar)	30	10
E	Injection Time (sec)	1.3	1.36
F	Hold Time (sec)	3	4

**TABLE III: Preliminary experiments**

Experiment No.	Process variables						Response
	A	B	C	D	E	F	
1	+	+	+	+	+	+	7.95
2	-	-	-	-	-	-	7.71
3	+	+	+	+	+	+	7.9
4	-	-	-	-	-	-	7.65
5	-	-	-	-	-	-	7.65
6	+	+	+	+	+	=	7.95

Full Factorial Diagram (FFD) was then constructed to determine the degree of impact of these three factors. Table VI and Table VII were created by using the results of important factors. From table VIII it was observed that factor D (hold pressure) has the most significant effect on the variation (Red X). Factor of secondary importance, Pink X, is E (injection time). The third important reason for variations in the length of the resulting (Pale Pink X) is interaction between factor D and E.

**TABLE IV-Determination ratio and Control limits.**

Experiments	+ Level	Level
Initial	7.95	7.65
1 st Replication	7.9	7.71
2 nd Replication	7.95	7.65
Mean	7.933	7.670
Range	0.050	0.060
Dm	0.263	
R (bar)	0.055	
Dm/R (bar)	4.788	
CL (best)	8.018	
	7.849	
CL(worst)	7.754	
	7.586	

**TABLE V: Main experiments, Swapping and capping runs**

EXPERIMENT NO.	PROCESS VARIABLES	RESPONSE (cm)	CONTROL LIMITS	RESULT
1	A(+) OTHERS(-)	7.85	7.586-7.754	A is not important
2	A(-) OTHERS(+)	7.95	7.849-8.018	
3	B(+) OTHERS(-)	7.3	7.586-7.754	B is not important
4	B(-) OTHERS(+)	7.93	7.849-8.018	
5	C(+) OTHERS(-)	7.95	7.586-7.754	C is important
6	C(-) OTHERS(+)	5.8	7.849-8.018	
7	D(+) OTHERS(-)	7.95	7.586-7.754	D is important
8	D(-) OTHERS(+)	7.25	7.849-8.018	
9	C(+)D(+) OTHERS(-)	7.95	7.586-7.754	capping run is unsuccessful
10	C(-)D(-) OTHERS(+)	7.73	7.849-8.018	
11	E(+) OTHERS(-)	7.95	7.586-7.754	E is important
12	E(-) OTHERS(+)	5.5	7.849-8.018	
13	C(+)D(+)E(+) OTHERS(-)	7.75	7.586-7.754	capping run is successful
14	C(-)D(-)E(-) OTHERS(+)	7.85	7.849-8.018	
17	F(+) OTHERS(-)	7.65	7.586-7.754	F is not important
18	F(-) OTHERS(+)	7.9	7.849-8.018	

**TABLE VI: Important factors by their levels**

		C+	C-
D+	E+	7.95,7.9,7.95,7.75 MEDIAN = 7.925	6.03 MEDIAN=6.03
	E-	7.95,5.5 MEDIAN=6.725	7.95 MEDIAN=7.95
D-	E+	7.2 MEDIAN=7.2	7.95,7.73 MEDIAN=7.84
	E-	7.95 MEDIAN=7.95	7.65,7.65,7.71,7.85 MEDIAN=7.68

**TABLE VII: Important factors for preparation of factorial analysis**

	FACTORS			RESPONSE	MEDIAN
	C	D	E		
1	+	+	+	7.95,7.9,7.95,7.75	7.925
2	+	+	-	7.95,5.5	6.725
3	+	-	+	7.2	7.2
4	+	-	-	7.95	7.95
5	-	+	+	6.03	6.03
6	-	+	-	7.95	7.95
7	-	-	+	7.95,7.73	7.84
8	-	-	-	7.65,7.65,7.71,7.85	7.68

Making a simple mathematical equation based on the contribution of significant parameters, the optimal setting was decided.

$$Y=7.413+ 0.0375C - 0.255D - 0.16375E + 0.13CD + 0.27625CE - 0.01625DE + 0.50375$$

As response 'Y' considered is defective injection moulded product, our objective was, lower the better. Using above equation, offline iterations were done.

Experiments were carried out changing the levels of the parameters, response for setting in case of experiment no. 10 (shown in table IX) that resulted in defect free products and hence considered as an optimum output. Conclusions of the earlier phase (identified optimum levels of the parameters as shown in the table X) were used as an input to find the improvements in the next phase.

Validation of optimum parameters using B vs.C was then done. Further, the result clearly validated the improvement against the criteria mentioned in table XI and XII.

**TABLE VIII: Main and interaction effects and factorial table**

	MAIN FACTORS			INTERACTIONS				RESPONSE
	C	D	E	C*D	C*E	D*E	C*D*E	
1	+	+	+	+	+	+	+	7.925
2	+	+	-	+	-	-	-	6.725
3	+	-	+	-	+	-	-	7.2
4	+	-	-	-	-	+	+	7.95
5	-	+	+	-	-	+	-	6.03
6	-	+	-	-	+	-	+	7.95
7	-	-	+	+	-	-	+	7.84
8	-	-	-	+	+	+	-	7.68
MEAN(+)	7.45	7.1575	7.24875	7.5425	7.68875	7.39625	7.91625	
MEAN(-)	7.375	7.6675	7.57625	7.2825	7.13625	7.42875	6.90875	
DIFFERENCE	0.075	-0.51	-0.3275	0.26	0.5525	-0.0325	1.0075	
COEFF.	0.037	-0.255	-0.164	0.130	0.276	-0.016	0.504	CONSTANT 7.413

**TABLE IX: Offline iterations and its calculated responses.**

EXPT. NO.	C	D	E	CONSTANT	RESPONSE	REMARK
1	0	0	0	7.413	7.413	
2	1	0	0	7.413	7.451	
3	2	0	0	7.413	7.488	
4	0	1	0	7.413	7.158	
5	0	2	0.2	7.413	6.864	DEFECTIVE
6	0	2	0.5	7.413	6.805	
7	0	2	0.6	7.413	6.785	
8	0	2	0.7	7.413	6.766	DEFECTIVE
9	-1	2	0.7	7.413	5.570	OK
10	-2	2	0.75	7.413	4.235	OK
11	-2	3	0.75	7.413	2.952	MATERIAL PURGES OUT
12	-3	4	0.8	7.413	-0.9615	DEFECTIVE

**TABLE X: Existing and Optimum Settings**

SR.NO	FACTORS	EXISTING SETTINGS (-VE)	OPTIMUM SETTINGS
1	CYLINDER TEMPERATURE	120	105
		110	102
		100	100
2	INJECTION SPEED	60	34.5
3	INJECTION PRESSURE	80	120
4	HOLD SPEED	10	7
5	HOLD PRESSURE	10	32
6	INJECTION TIME	1.26	2.05
7	HOLD TIME	4	3
8	COOLINGTIME	29	25
9	NOZZLE TEMPERATURE	140	120

**TABLE XI: B vs. C Response**

B VS C RESPONSE		
LOT NO.	BETTER(B)	CURRENT( C)
1	10	19
2	6	16
3	6	9
4	2	19
5	5	17
6	2	16
7	4	9
8	4	7
9	4	9
10	2	8
11	5	9

**TABLE XII: Criteria for validating improvements and results.**

B VS C ANALYSIS	
Better condition	optimum settings (table )
Current condition	-
Response decided for monitoring	% Rejection
Lot quantity(for batches)	117(B) 107( C)
Average of B	4.55
Average of C	12.54
Xb-Xc (Amount of imrovment)	7.99
Sigma(B)	2.3
Is [Xb-Xc] greater than [K*Sigma(B)]	
(Where K is std value k=2.96 @90%confidence level)	Yes [7.99 > 6.808]

## 5. CONCLUSION

This study focused on the usage of Shainin tool specifically, as it is easy to understand and involves simple mathematical calculations (so that bottomline people can also understand it very easily). Moreover, time required for training is also less, which is one of the important requirement in case of small scale units. The rejection level was reduced to 4% as compared to the earlier rejection that was 12%. The investigation and findings yielded promising results. A very important factor in the use of Shainin tool is that the data collection was done without disturbing the regular production.It helps in improving the quality progressively. The drawbacks of Shainin DOE are that it cannot be applied in the research and development phase of production.

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# Application of Internet of Things for Lean Practices: A Case of Connected Cars

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**Abstract:** Implementing the lean practices to increase efficiency has always been a challenging task for companies. This paper seeks to address how Internet of Things (IoT) could digitize the implementation of lean principles, thus creating value in the process. The primary aim of this study is to extend the scope of IoT, which is currently limited to manufacturing and few other industries. This has to be achieved by exploiting and adopting existing smart solutions from industrial and manufacturing industry. This paper provides an analysis of literature and existing IoT solutions on three paradigms of IoT namely: hardware, software, and connectivity. The Proposed approach is to study the existing IoT infrastructure and solutions by big IoT players and adapt it for an entirely different problem, possibly in another industry. Further in this paper, the proposed methodology is used to solve traffic congestion problem and to improve the current concept of connected cars.

**Keywords:** IoT, Internet of Things, Industry 4.0, lean principles, Value creation, Connected cars

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## 1. INTRODUCTION

“Value creation is the ultimate purpose as well as the central process of economic exchange.” (Vargo et al., 2008). The purpose of a business is to create value, deliver it to customers and capture profits in an efficient way. “Efficiency” is the key differentiating factor between success and failure in any given industry. Various literature on increasing the efficiency and value creation conclude at ‘Lean’. Lean thinking is simplification and elimination of wasteful tasks, the non-value adding processes. Technology is continuously transforming the ways in which companies operate by reshaping the nature of products, processes, strategies, business model and competition (Porter and Heppelmann, 2014). One such technology is ‘Internet of Things’ (IoT), an extension of the internet and the web into the physical realm by widespread deployment of connected, smart devices.

Before going into any further discussion, we need to understand the concept and principles of ‘lean’. Lean thinking originates from ‘Toyota Production System (TPS)’ or ‘Just-in-time (JIT) Manufacturing’ developed by T. Ohno (1988) (and later studied by Womack, and Jones, 2003). Simply stated, Lean is everything that aims at eliminating waste and non-value adding activities from the chain. The seven kinds of wastes that need to be eliminated are (i) Overproduction, (ii) Unnecessary transportation, (iii) Excess inventory, (iv) Unnecessary motion, (v) Defects, (vi) Over-processing and (vii) Waiting. Jefferey K. Liker recommends various tips for implementing ‘lean’. There are a plethora of research papers discussing different approaches for achieving the same. The common feature is data. Things can ‘t be improved if they can’t be measured.

IoT will allow a very large number of sensor-enabled smart devices to produce data and communicate with other devices or humans, generate insights for human operators or completely automate a process, eliminating human intervention. IoT-enabled industrial and manufacturing engineering is often labeled as 4th Generation Industrial Revolution or Industry 4.0, led by Germany. It is predicted that by 2020, the number of IoT devices would reach 50 billion. Atzori et al. (2010) indicate that there are two main components that enable the IoT: (i) Sensors and communication hardware and (ii) Big Data storage and analytics, i.e. software solutions. Lean principles depend upon data to figure out the problem and resolve it. IoT has the potential for exhaustive data collection and processing. Hence, IoT can digitize the application of lean methods and change the whole game.

There is a lot of literature which addresses the servitization of manufacturing industry using IoT approach; smart industry, Industry 4.0 etc. IoT is no longer limited to manufacturing industry and is finding ever-increasing application in the service industry. But there is still need for research in this area. The research objective is to broaden the horizon of problems, which can be solved using application of IoT. The objective is achieved by literature review, case study research and mapping existing solutions on similar problems; then we apply the proposed methodology to solve the problem of traffic congestion.

## 2. LITERATURE AND CASE STUDY REVIEW

Existing works of Stuart C. K. So (2010) discussed the application of Radio Frequency Identification (RFID) to apply ‘lean’ principles in apparel retail. Connected system

improves the visualization of a shop and helps locate the misplaced items, resulting in better customer service.

Sharma and Gandhi (2016) discuss the challenges and scope of implementing lean practices in shipbuilding. Their work gives the unconventional insights of lean implementation, expanding the knowledge base.

Anna R., P. Helo, and A. Gunasekaran (2017) explore the IoT powered servitization. Though their work is limited to manufacturing industry it is one of the finest work exploring and expanding the scope of IoT. Their suggested methods can be adapted and extended for any industry.

T. Saarikko, U.H. Wetstergren, and T. Blomquist (2017) with their work and Xia F. et al. (2012) in their editorial summarize all the developments in the field of IoT. They highlight the other important aspects of IoT like security concerns and energy efficiency of the system, which are easy to overlook.

The case study was selected as the research method since its characteristics were deemed to be particularly suited to the purpose of the research presented in this paper. Yin (1981)

states that case studies allow for studying certain a phenomenon in a real-life context, especially when the boundaries between a phenomenon and its context are not clearly evident. Stake (2005) claims that the multiple case study method is also directed by the fundamental question of what helps us understand the studied phenomenon. Stake (2005) also claims that the multiple case study method is useful when addressing more than one research question, which the case with this study.

To make up for the inherent weakness of this approach and to ensure the integrity of the research process and its scientific rigor, 75 case studies were studied. To ensure a holistic view, the study was performed for three different IoT solutions providing companies. As identified earlier the key IoT-enabling technologies are hardware, communication, software. The companies were (i) CISCO (communication), (ii) HCL (software), (iii) Intel (hardware).

The industry of application, unique challenge faced, ingenious solution deployed and impact created were studied for each case and findings are tabulated below.

**TABLE I : CISCO: Case Study matrix**

PROJECT	INDUSTRY	CHALLENGE!	SOLUTIONS	IMPACT
ALASKA DOT	TRANSPORTATION	Reliable communication in harsh weather conditions	- Cisco connected roadways    - Cisco instant connect (LMR)    - Cisco unified communications solutions	- Fast response to emergency situations    - Achieve significant equipment mgmt. and maintenance efficiency
DAIMLER TRUCKS	MANUFACTURING	- Improve agility and efficiency    - Enhance visibility and operations efficiency    - Improve mobile communication	- Converged plantwide ethernet (cisco AIRONET)    - Robust, standards-based security compliance    - Rockwell automation architectures	- Reliable, secure connectivity    - Enhanced network security    - Real-time, remote troubleshooting and visibility, minimizing downtime
STANLEY BLACK & DECKER	MANUFACTURING	Visibility of real-time overall equipment effectiveness and line productivity in complex manufacturing environment	- AEROSCOOUT real-time location system (RTLS)    - Cisco wi-fi infrastructure and plantwide ethernet	- Equipment effectiveness: +24%    - Labelling defects: -16%    - Inventory and material holding cost: -10%    - Immediate notification of any line issue
BRITISH COLUMBIA HYDRO UTILITY	ELECTRIC UTILITY	- Enable remote automation and monitoring in smart grid    - Connect applications over a common, secure network	- Cisco field area network and advanced metering infrastructure    - Cisco ISE and connected firewalls, mobile devices and systems	- Controlled power outages    - Increased data collection from once every two months to twice a day    - Improved visibility for remote devices across the grid
CONNECTED CITIES: MISSISSAUGA	GOVERNMENT: SMART CITY	- Improve services and drive operational efficiencies    - Open and accessible government	- Cisco routing, switching and security solutions    - Citywide wireless network	- Faster response of operations team and emergency services    - Improved public safety with immediately actionable information
CALSTAR	AVIATION AND HEALTHCARE	Simple, invisible communications among the CALCOM, flight crew, medical teams, first responders and hospitals	- Cisco unified communications solutions    - Cisco instant connect    - cisco unified survivable remote site telephony	- Accelerated lift times    - Simplified communications and increased accuracy for high situational awareness    - Enhanced operational control
AUSTRIAN AUTOBAHN CONNECTED ROADWAYS	TRANSPORTATION	Connect 6,500 cameras and 70,000 sensors on 2,200 km of roadways	- Cisco IPICS for centralised and fast communications to any device or system    - Cisco network of switches and routers	- Exceeded EU standards for road transport    - Cost reduction by better road utilization    - Connected roads, drivers and authorities nationwide

**TABLE II : HCL: Case Study matrix**

PROJECT	INDUSTRY	CHALLENGE!	SOLUTIONS	IMPACT
PAPERLESS TRUCKING SYSTEM	LOGISTICS	- Optimize fleet of trucks to efficiently execute work orders and communicate it to driver through a logistics control centre    - Paperless transaction	- Application portal and network equipment for automation of truck movement and payment    - Sensor for real-time location and weight of truck load	- Reduced processing lag time to less than a week    - Revenue increased by 3x    - Paperless transaction for waste reduction
REMOTE ACCESS AND MONITORING	PROCESS ENGINEERING	REDUCE NUMBER OF SERVICE TRIPS BY SEAMLESS DATA ACQUISITION FROM MULTIPLE buses	- DATA COLLECTION FROM VARIOUS FIELD DEVICES ON A SINGLE PLATFORM    - DATA MANAGEMENT AND SECURITY	- REDUCED SUPPORT COST BY 15%     18000+ CUSTOMERS IMPACTED
CONNECTED MEDICAL DEVICES	HEALTHCARE TECHNOLOGY	- Improve quality of customer service    - Generate insight to innovate new products	- Remote monitoring solutions and machine data usage    - End-to-end support for remote installation and monitoring    - HCL's platform acceleration suite	18% reduced field visit cost    - Improved device uptime by 27%    - Better product insight to R&amp;D
OPERATION SAFETY AND SECURITY	MINING	- Enhance worker safety in accident prone and blast sites    - Predict machine malfunctioning	- Smart jacket and smart helmet    - Geo location tracker    - Vehicle proximity alert    - Machine monitoring and ambient climate monitoring	- Blast toll-call reduced from 3-4 hours to 5 minutes    - Reduction in maintenance task time    - Reduction in number of accidents
REMOTE VEHICLE DIAGNOSTIC	AUTOMOTIVE	Correct slow vehicle diagnostic and high lag-time in corrective actions due to limited usage information availability	- Near real-time collection of diagnostic data from vehicles    - Analytics engine for analysis of diagnostic data: alert/ notification    - Vehicle performance data readily available    - Service delivery platform: customer &amp; reseller management    - Capabilities for customer life cycle management, accounts management, payments and settlements	- Customer satisfaction: +30%     25% enhancement in vehicle performance by introducing analytics for OEMs
REPLENISHMENT MANAGEMENT SOLUTION	PRODUCT AND SERVICE	Integration of distributors and resellers in the service delivery chain in centralised reporting system		- Reduced time-to-market by 40%     100mn USD cost saving in 15 months
SMART PARKING	PARKING SOLUTION PROVIDER	Set up centralised control centre and remote monitoring of multi-facility parking	- Software engineering solution    - System integration with legacy system	30% increase in revenues     40% reduction in time-to-market
PREDICTIVE MAINTENANCE ANALYTICS	AIRCRAFT DESIGN AND MANUFACTURING	Proactive predictive diagnostics by analysing enormous volume of aircraft data	- Agile analytics approach for seamless data acquisition, cleansing and harmonization    - Service event related data analytics	- Reduced time to insight from 30-90 days to one day    - Initial accuracy: 75%

**TABLE III: Intel: Case Study matrix**

PROJECT	INDUSTRY	CHALLENGE!	SOLUTIONS	IMPACT
LEVI'S STORE	RETAIL	Improve in-store experience and generate customer insights	- Intel trusted analytics platform (tap)    - RFID tags, in-store sensors and gateway system	- Improved inventory accuracy    - Fewer missed sales    - Enhanced efficiency    - Greater agility    - Tailored content    - Improved operational efficiency
DUNKIN DONUTS	RESTAURANT	Improve customer experience and operational flexibility	NCR VitalCast digital signage replacing static menu boards	- Headquarters now generates one third more energy than it consumes    - GoService IoT
KINGSPAN	BUILDING MATERIAL	Transform Kingspan headquarters into a net-zero energy building	- Intel IoT gateway    - Kingspan smart building material solutions	- Identification of potential faults by monitoring data and proactively plan service to customer    - Product insight to improve production line
FUSHENG	AIR COMPRESSORS	Secure IoT smart service platform to collect sensor data from air compressors	AdLink intelligent IoT gateway	- Fleet management for efficient movement of customers and freight    - Rich all know customer experience    - Improved control and management
ZURICH AND FRANKFURT AIRPORT	AIRPORT OPERATIONS	Improve customer experience for billions of customers moving every year by removing inefficiencies in fleet management	- Cobus buses fitted with sensors and cameras to track real-time data and displays to communicate with customers    - Advantech DLOG trek-550    - Inform GMBH GroundStar real-time application	
MALAYSIA: SMART RICE IRRIGATION	AGRICULTURE	Decentralised control of water gates for improved flexibility and quick response	- Kontron industrial computer platform a-201    - Intel IoT gateway	- Doubled production of rice converting Malaysia from importing to exporting country    - Remote monitoring and control
HSINCHU: SMART CITY LIGHTING	SMART CITY	Cloud-based street lighting system to improve energy efficiency and better maintenance	- Intel IoT gateway    - IEN intelligent environment network services    - ZigBee wireless network	58% energy-saving rate     \$ 34.35 million saved on energy cost by replacing 70% of street lights    - Brightness control
CASCADE3D CONNECTED CARE	HEALTHCARE	Improve residential care by extensive monitoring in least restrictive way	- Medical sensors, equipment and smart home management solutions    - Intel IoT gateway	- Reliable, remote monitoring for data driven healthcare support    - More frequent health updates to care workers directly on their phones
CAIXA BANK	FINANCIAL SERVICES	Eliminate paperwork by enabling digitized biometric signature solution	- SERBAN biometrics solution    - Quick access and secure storage of digital documents    - Intel powered Fujitsu biometric capable devices	- Saved 30% office space per branch    - Around 90% operations digitized    - Reduced processes involved in document management by 50%
FUJITSU	MANUFACTURING	Real-time tracking and visual mapping of products and related information	- Intel IoT gateway    - Fujitsu cloud service IoT platform	20% reduction in rework lead times     30% reduction in shipping costs

### 3. CASE STUDY: CONNECTED CARS SOLUTION

The interesting fact in the whole application of IoT solution is that all the key components required for successful implementation of IoT already exists, in either refined or crude form. The implementation is therefore not technologically limited. Therefore, in this study, more focus is on evolving a new perspective to look at existing solutions and mapping the solution onto other problem, which might be in entirely different. And less on figuring out the technology. For demonstration and verification of this approach, the problem of traffic congestion at intersections was chosen.

#### 3.1 Problem Definition

The problem of traffic congestion is not an uncommon phenomenon. A scene where a traffic police sorts the traffic congestion at an intersection is not unheard of. The economic, social, environmental and health implications of traffic are well researched and understood. Europe losses around 1% of its gross domestic product in congestions. It cost America, \$124 billion in year 2013. 25% of European Union's greenhouse emission is credited to traffic. In India, it costs 960 crores a day. In Delhi, a person wastes 52, 584 man-hours in traffic, annually.

#### 3.2 Existing Solutions

**Intelligent Traffic Management:** ITM Systems (Intelligent Traffic Management) employ traffic counters, CCTV cameras, satellite images and historical data etc. to study the traffic patterns. The problem is combated by manipulating traffic lights, varying speed limits or by displaying on navigation systems of a vehicle.

**Connected Vehicle:** Connected Vehicle (CV) or more popularly known as Connected Cars Concept is an IoT powered solution to defeat traffic. It incorporates all the functionalities of ITM Systems. IoT allows data flow between Vehicle to Vehicle (V2V) or/ and Vehicle to Infrastructure (V2I). V2V and V2I communication allow all the required data to predict and actively avoid not only congestions but also 'traffic waves'.

#### 3.3 Drawbacks

The existing literature and solutions depend on fleet management approach to actively avoid traffic. These solutions have been implemented in smart city projects and were quite successful. But the biggest drawback is that, although these solutions can actively avoid traffic congestions, these cannot actively dissolve one. There is still need for human intervention, say in case there is a congestion at an intersection. The unsatisfactory resolution of the data collected is another drawback.

#### 3.4 Mapping

In 'Zurich and Frankfurt Airport' case study by Intel (given above), the problem was to remove the inefficiencies of fleet management system to improve customer satisfaction. Dubai International Airport is another case where a similar problem was solved leveraging the power of IoT. Biggest international airports deal with biggest volumes of passengers. Daily. Assisting every passenger with directions is a gigantic task. The IoT solution was to deliver the directions on passengers' smart devices. The directions can be personalized for every passenger and made instantly available on screens. Another part of the solution is fleet management using pre-installed displays. This solution can be mapped and adapted to solve the traffic congestion problem.

#### 3.5 Proposed Solution

A small on-board IoT device can be installed on the steering wheel or handlebar of all vehicles. The device can communicate to other devices (V2V) and IoT infrastructure installed on sides of a road or at an intersection (V2I). The device can communicate the driver's intended direction (from direction indicators of a vehicle), vehicle's location via. GPS and vehicle's identity and its dimensions. All the collected data is sent for processing to a central processing system. The dimensions and condition of roads are built-in into the system. The traffic and road data can also be verified by analyzing existing CCTV infrastructure. In a situation of traffic congestion at an intersection the data in ran into an algorithm, which evaluates an efficient sequence of motion which all individual vehicles must follow to dissolve the traffic. The sequence then is broken into a series of simple task (like move forward, move towards right/left, stop, wait) all individuals must carry out and is displayed on the device's screen. Hence, automating the traffic police's job which means eliminating human intervention from the process.

The process is expected to generate data with better resolution, which can be clubbed with existing ITM System and connected car solutions for fleet management, traffic light manipulation, traffic wave detection, variable speed limits etc. This improves the communication between the drivers and system, especially from system to driver. Since the output is personalized for each driver it can provide better control of traffic flow, provided drivers follow the suggestions.

### 4. CONCLUSION

The research presented in the paper explores the untapped potential of IoT solutions to solve any problem. The aim of this paper is to explore and broaden the horizon of problems which can be solved with IoT approach and more importantly, to adapt the existing solution to solve an

unaddressed problem or a problem in a better way. This is achieved by the study of existing solutions and proposing “mapping solution to other problem” approach. As presented in this paper, an innovative solution for connected cars and traffic management derived from studying the IoT based smart Airport operations system.

The researchers acknowledge certain limitations of the study. The use of case studies as a research method has been criticized for its false promise of allowing in-depth analysis of a given phenomenon. The lack of data and reliance upon qualitative data can also be perceived as a limiting factor. It has been argued that qualitative case study may be overly influenced by the researcher. It can also be argued that qualitative case study may have overlooked critical aspects. This opens an avenue for further research and future study.

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# A Case Study on Implementation of Lean Manufacturing Tool- 5S' in Pressure Vessel Manufacturing Company

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**Abstract:** Lean manufacturing is an approach focused on improving quality; reducing variation and eliminating waste in an organization. This research provides a roadmap and implementation of lean manufacturing tools in pressure vessel manufacturing industries. The main objective of this paper is the study and analysis of improvements in pressure vessels, heat exchanger and separation pressure vessels, where the entire project has been done. Getting these improvements, using the initial resources, it is obtained some benefits, adding more production and easiness to work in general. Also there is an improvement in terms of quality. To make the project, gather data tools have been used. Applying lean Tools and formats, an initial study has been made and then proposal improvements. After analyze the results, it is possible to show positive conclusion using LM as an optimization method, because currently, there is more space less time used and better quality in the final product. These papers represent the one case study in pressure vessel manufacturing company, where the 5S' tool implemented. The main Objectives are decreasing Inventory, more Utilization of space, Reduce Wastages.

**Keywords:** Lean Manufacturing, 5S

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## 1. INTRODUCTION TO LEAN MANUFACTURING

Lean manufacturing is a business philosophy that continuously improved all process involved in manufacturing process irrespective of what type of product being manufactured. India is one of the fastest growing economics of the world. It is provides highest level of customer service through systematic and continuing searching non-value-added activities and wastes and eliminating them. Lean Manufacturing is mainly adopted by organizations in order to reduce wastes and improve the quality of products. In India small and medium scales industry has been very successfully in improving quality of products, because products are tested at each every step in the manufacturing process .The concept of lean production arrived to India in the mid 1980's from Japan and united states of arriving, but it was mostly the larger companies that adopted the techniques now the small and medium companies has started to the Lean manufacturing concept's. This gives the extra edge in today's cost and time competitive in small & medium scale Industry in Indian Markets, they are Price, and Quality and delivery Lean enterprise owners can deliver high quality products with low prices.

## 2. LITERATURE REVIEW OF LEAN MANUFACTURING

During the research review, we found that Lean thinking constraints in traditional batch manufacturing environments^[1], Development of 5s Practice checklist for environment, housekeeping and Manufacturing Industry^[2]. Lean methodologies economically and environmentally sustainable foundries^[3] is often seen as a set of tools that

reduce the total cost and improve the quality of manufactured products the lean management is philosophy is one which targets waste reduction in every facet of the manufacturing business. Metal casting industries are actively involved to reduce the scrap rejection and rework during the manufacturing process of the components. To achieve these production concerns must follow the quality control procedures correctly and timely implementation of the lean manufacturing^[4]. The lean manufacturing of small industry could Implementation the philosophy in own contend lean production concept successfully, an investigation in two middles sizes industries, India^[10]. Value stream mapping technique involves flowcharting the steps, activities material flows, communications and other process elements that are involved with a process or transformation. In this respect, value stream mapping helps an organization to identify the non –value –adding elements in a targeted process. Different flow layouts are selected that reduces the transport time^[6], production leadtime and lower –in-process inventory^[8]. The proposed framework for lean sigma implementation need to be validated in different scenarios for establishing its validity^[5] and the ultimate goal of this system is to focus on achieving total communication efficiency that uses Green and lean TQM system^[7]. Lean manufacturing philosophy asks for elimination of wastes widen in the manufacturing system by focusing on products value stream and eliminating non value adding activities through continuous improvement ^[9]. An equipment replacement decision problem within the context of lean manufacturing implementation. We provide a roadmap for how VSM can provide necessary information for analysis of equipment replacement Decision problem encountered in lean manufacturing^[11].

From the literature review, we conclude that in the different direction, the various researches done on the lean manufacturing tools and techniques but there is less number of companies aware about the LM tools and implementation of the same. So we implemented the 5s' concept in the pressure vessel company.

### 3. METHODOLOGY

From the literature survey, we are getting lots of idea regarding to lean manufacturing and we are preparing a methodology to complete this project work are as:

#### 3.1 Observation and Measure of 5S before implementation

With the help of 5S score card, we measure the 5S score before implementation.

#### 3.2 Preparation of 5S team

With the help of departmental manager and company's CEO, we prepared the 5S team and their roles and responsibilities.

#### 3.3 Implementation of 5S

By taking the score card of the 5S before implementation and getting the idea about the step by step implementation of 5S in particular area of the organization.

#### 3.4 Periodic Improvement through 5S

We also measure the periodic (15-days) measurement of the 5S score to check the periodic improvements in the implementation of 5S.

#### 3.5 Comparison of before and after implementation of 5S

After successfully implementation of 5S, we compare the before and after implementation of 5S (after 6-months).

#### 3.6 Conclusion

From the comparison, we get the impact of the 5S in the organization.

### 4. CASE STUDY

#### 4.1 A Company Profile

**Name & Address:** Maruti Industries, Sachin, Surat

**Products:** Pressure Vessels, Heat Exchanger, Jumbo bags etc.

**No. of Peoples work:** 35

#### 4.2 Observation and Measure of 5S before implementation

##### 4.2.1 Observation before 5S implementation

1. It is observed that in the machine shop the time taken to find out any tools as specially drill tools by the

machinist from the tool bar in the inventory place is too time consuming.



2. The arrangement of required pipes in the fabrication shop is not proper so to identify the S.S pipes are difficult and time consuming.



3. Wastages are not proper managed.
4. There is no any layout prepared in the machine shop.



5. There is no any safety related charts or labelling in the machine shop.



#### 4.2.2 Measure of 5S before implementation

Before implementation of 5S, we would like to measure the 5S score for the same we used one standard format.

#### 4.3 Preparation of 5S Team

After detail observation my first aim is to make a 5S team, so with the mitigating action with the management of the organization we prepared a 5S Team in which the leader, team members and group members are define. According to responsibilities given to the 5S team it must that the step by step implementation of 5S with the Safety and measure after 15-days for further improvements.

#### 4.4 Step by Step Implementation of 5S

As we seen that the actual situation of the organization before 5S implementation, so according to fulfill all the requirements we are going to step by step implementation of the system.

1. According to requirement of operator in the machine shop, Sort out the drill bits and proper arrangement was done. Due to this arrangement it is easy to find out the drill bits and around 80 percentages less time required to find out the tool bits by the machinist



2. In the fabrication shop, it must that the sort out the pipes according to specification and arrange them by preparing the rack for the pipes in the raw materials shop. Due to this arrangement it is easy to find out the S.S pipes and it covers less space in the fabrication shop.



3. Proper dispatched area for the wastage is found and arranges them. Dispatching of the metal chips is not done in the proper way; we observed that all the metal chips are around the machine. So we found the area



for the dispatching the metal chip and supply it in once per week.

4. Preparation of the layout in the machine and



fabrication shop. Proper preparation of the layout of the plant is very important it reduces material movement time, reduces the accidents, define a proper work area and it's a shine of the organization. So we prepared the proper layout for the "Maruti Industries" and it's get the advantages from the same.

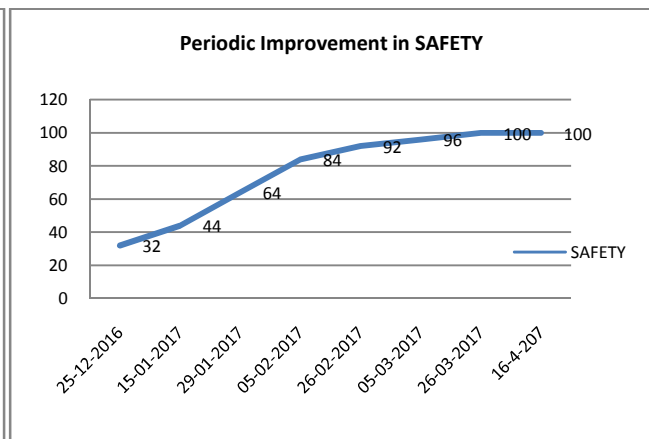
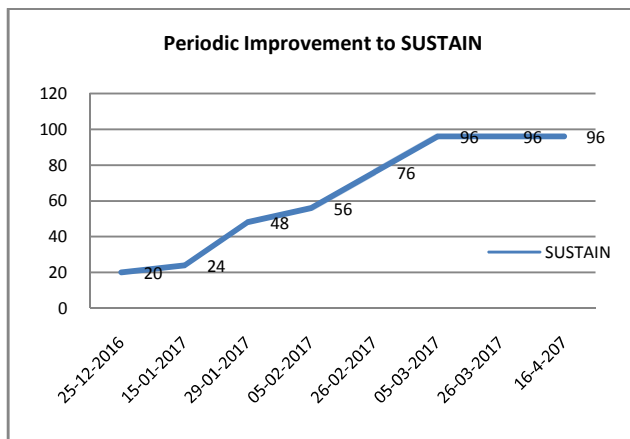
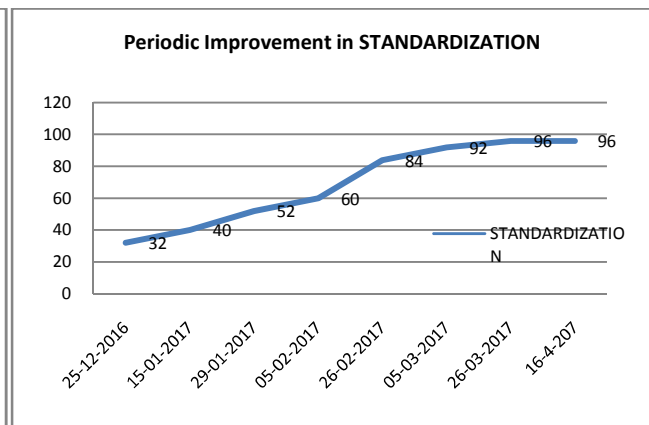
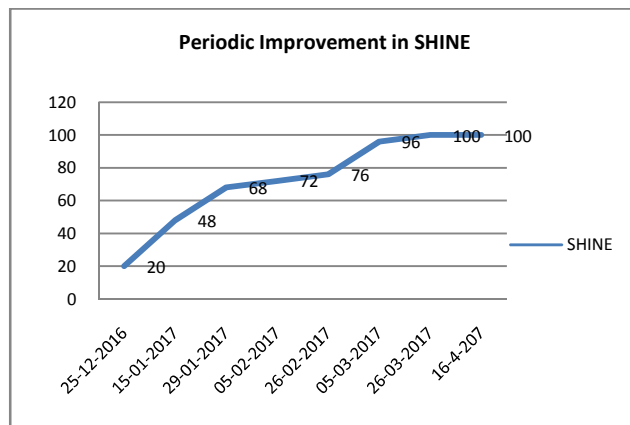
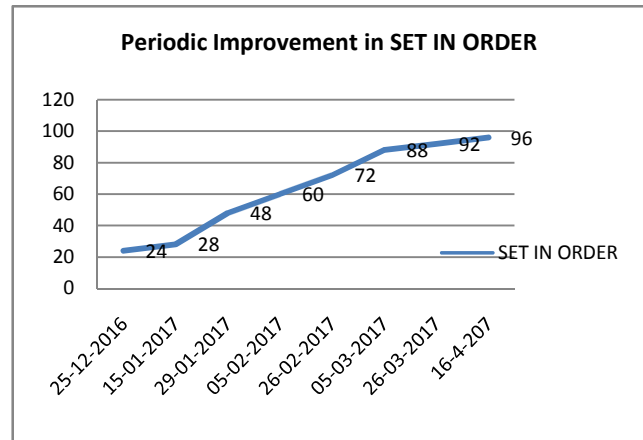
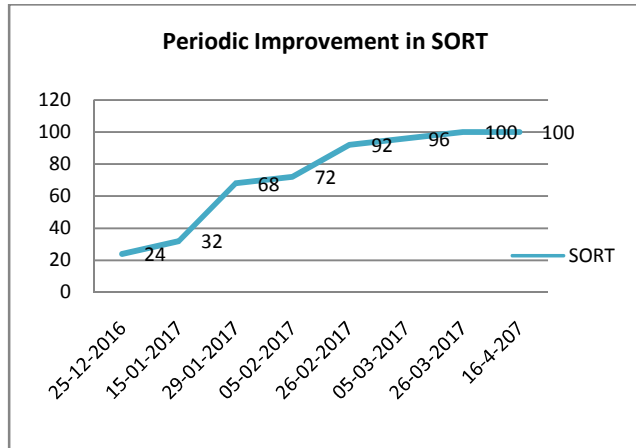
5. Labelling the machine and also prepared safety slogan and displayed in the shop



#### 4.5 Periodic Improvement in the 5S (Measure by 5S score Card):

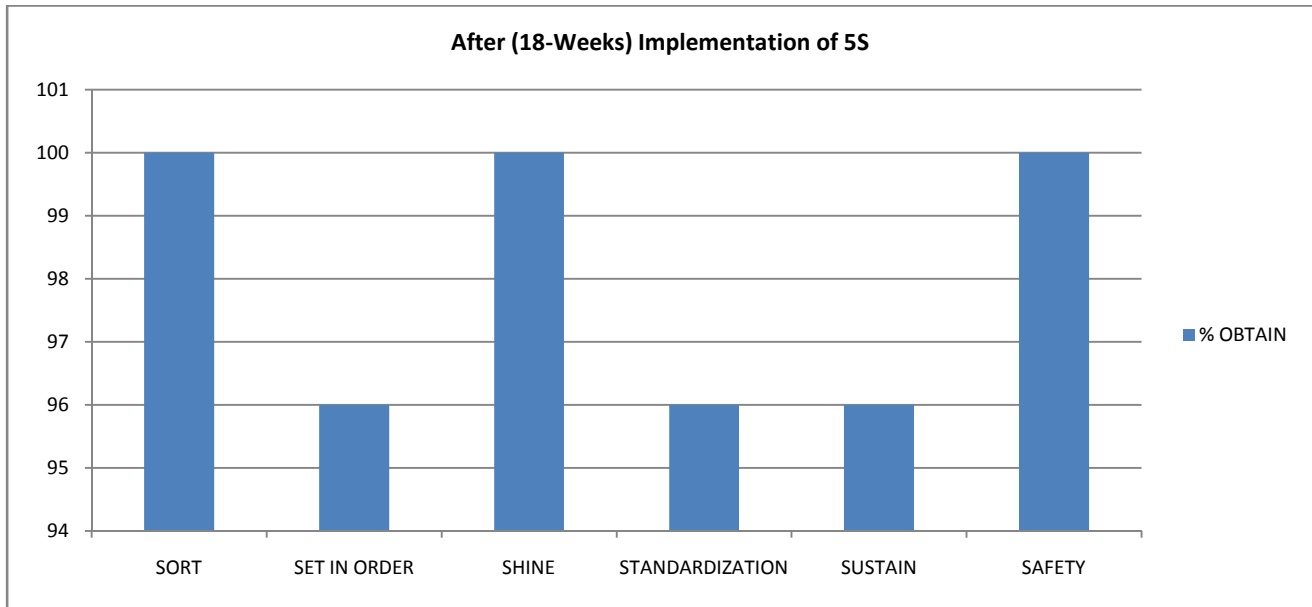
Whenever we start to implement the 5S then also with the help of score card every 15-days to measure the 5S for

further improvement and action taken. The periodic improvement in the 5S is given below from the date of start in the month of December 2016.



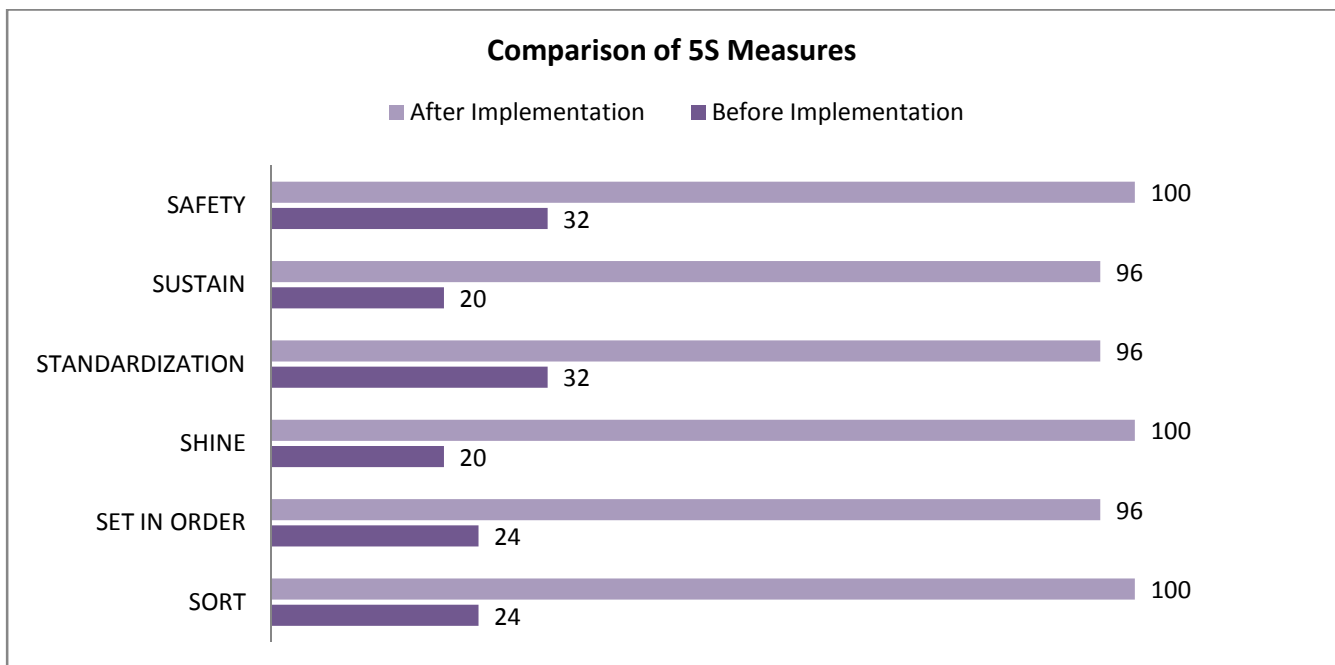
#### 4.6 Measure of 5S Score after Implementation

After implementation and maintaining the 5S for the three months, we would like to measure the 5S score with the help of score card.



#### 4.7 Results And Discussion

After implementation it must to maintain it for a longer period of time. So I have measure the periodic improvement and then compare the same of before and after implementation of 5S.



## 5. CONCLUSION

From the above comparison it is conclude that the Lean Manufacturing 5S tool is successfully implemented. So it helps the management to create a proper work environment for the employee and it set the mind of worker to achieve the goal of quality and productivity. It also increases the overall performance of the organization.

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# Application of SMED in an Extrusion Stretch Wrapping Machine and Layout Modification of Deburring Station in a Manufacturing Industry at Nagpur

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**Abstract:** This paper illustrates the application of SMED in a manufacturing industry. The study is executed in an aerospace component manufacturing industry at Nagpur. The approach to improve the productivity by minimizing the die exchange time in extrusion stretch wrapping machine. The changeover process of die is recorded having enormous amount of time which is non-value adding in full sense. The existing die change over time is minimized almost by 60% using SMED (Single Minute Exchange of dies). This reduction in time is achieved by combining the processes, use of effective tools and equipment and by eliminating idle time. The layout modifications are also suggested and implemented in deburring section. Multi-dimensional objectives of productivity, safety and human comfort are achieved by proposing a better layout which ensures minimum material flow, less chances of accidents, streamlined unidirectional flow, and effective utilization of space. The implementation of SMED reduced the cost of manufacturing as well as the changeover time. The study provides insights for massive scope for improvement in layout and processes which can contribute to the productivity, quality and cost reduction.

**Keywords:** SMED, changeover time, layout improvement;

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## 1. INTRODUCTION

TAL Manufacturing Solutions Ltd, is one of the leading companies in India, successfully delivering manufacturing solutions for over 40 years to customers in automotive and heavy engineering and more recently in aerospace and defense services. TAL – Aerospace Business Division is one of the leading solutions providers in Aerospace sector for Composites, Aero structures, Machining, Welding, Assemblies, Aero Tooling, Ground Support Equipment & Ground Handling Equipment to Global OEMs and Tier-1 Suppliers. This reputation has been built around well-structured strategy, whose key elements are – lean manufacturing, continuous improvement, business systems, contract flow down & compliance including to supply chain partners, training & development, measuring, monitoring and control of metrics' across all areas of operations. All of these are with a view to bring in quality, productivity, reliability, repeatability and transparency in meeting customer expectations around metallic and composites manufacturing and assembly. TAL has a well-established and effective Project Management System to plan, deploy and execute new projects into serial production in a short period of time.

With the growing shortage of skilled manpower, ever-increasing wages, IR issues with existing labor unions and changes in regulatory framework, there is a strong case for adopting automation in the industry. With its vast experience in providing manufacturing solutions and

competencies in mechatronics, TAL has developed articulated industrial Robots in the range of 2-5-10 kg payload and now offers cost effective automation solutions to the MSME in India. With its modular and optimum design, higher flexibility and significantly lower cost of ownership, the BRABO is revolutionizing automation in the MSME in India.

With its highly experienced and committed team, TAL is well placed to provide complete solutions and “BRABO” almost all your manual industrial activities. Integrator's and channel partners across the country have partnered with TAL to provide with the necessary support. We have also tied-up with banks to finance your cost of automation thereby, making it a profitable proposition from the day Robot is installed. BRABO is an Indigenous with a view to our everlasting customer centricity approach, cost of ownership is substantially lower due to its low maintenance cost, quick & cost effective spares availability and the sublime service assurance by us.

### **Machine Tools**

Metal cutting forms the bedrock of the industrial sector. Our range of standard and customized machines is capable of handling a wide variety of applications across various manufacturing industries. Built to perform 24 X 7, these machines offer the best available technologies. These machines offer not only Precision, Accuracy and Reliability

but also provide adequate safeties to create risk free working environment.

#### ***Special Purpose Machines***

- CNC - Vertical Lathe & Turnmill Center CTL
- CNC Vertical Machining Center (V - Series)
- CNC Vertical Machine Center (3R - Series)
- CNC Horizontal Machine Center (3R -Series)
- CNC - Parallel Kinematic Machine (Flexicut Series)

## **2. LITERATURE REVIEW OF THE ENABLERS OF KM ADOPTION IN SC**

The concept of lean manufacturing was developed for maximizing the resource utilization through minimization of waste, later on lean was formulated in response to the fluctuating and competitive business environment (Ali Allahverdi H.M. Soroush, 2008). The process of waste elimination is achieved through the application of lean tools and techniques (Dr.R.M.Warkhedkar,M.S.Desai, 2011). Lean manufacturing has its roots in automotive industry and it is derived from the Toyota Production System, the management philosophy that had been developed through decades by Toyota after the Second World War (Antonio Carrizo Moreira,Gil Campos Silva Pais, 2011). Lean system aims to improve value addition by means of removal of non-value added activities, making the value stream smooth, and converting push production to pull production and perfection by continuous improvement (Berna Ulutas, 2011). Lean Manufacturing is a multidimensional approach that embraces a wide variety of management practices in a unified system. These practices comprise just-in-time, quality systems, cellular manufacturing, work teams, and supplier management, among others (Dirk V Goubergen,Hendrik v Landeghem, 2001). As competition among companies increases, firms have been trying to find ways of having the competitive advantage in the market place (Ana Sofia Alves and Alexandra Tenera, 2009), and due to the intricacy of market order and competitiveness, many manufacturing organizations are under pressure to produce and dispatch products in shorter delivery times (Cakmakci M, 2009), hence to compete effectively short lead times are essential to provide customer satisfaction (Michels T.B, 2007), having materials flow along the production process, and long set-up times are an obstacle to the flexible use of production resources and are therefore a core production organization issue (Herr, 2014).

Another important issue in this matter is to gain flexibility, that defined as the ability of a system to perform proactive and reactive adaptations of its configuration in order to cope with internal and external uncertainties in production process that affect the materials flow (Trovinger and Bohn, 2005).

## **3. PROBLEM IDENTIFICATION**

Extrusion Stretch Forming machines operate by stretching the metal to its elastic limit, then wrapping the part around a forming die. This process increases the metal's yield strength and actually results in a stronger part. Since stretch forming machines also keep the metal under constant tension, they minimize imperfections such as "cans" or "buckles." Stretch forming machines also perform a task in one step that would otherwise require several machines and multiple steps, improving efficiency and saving time and money.

***Problem statement 1: To reduce the die change time on an extrusion stretch wrapping machine.***

The customer demand involves various different parts to be produced under a given time period. Since each part requires a different die (50 different dies) `

***Problem statement 2: To optimize the layout of a deburring shop with the objective to reduce the cycle time.***

Deburring is a non value added process in the given scenario so the time required to complete this operation should be minimized or eliminated. The problem is that the current layout and material flow of deburring shop was found to be improper in terms of storage of parts, man and material movement, cleanliness and cycle time.

## **4. APPLICATION OF SMED (APPROACH TO PROBLEM 1)**

SMED (Single-Minute Exchange of Dies) is a system for dramatically reducing the time it takes to complete equipment changeovers. The essence of the SMED system is to convert as many changeover steps as possible to "external" (performed while the equipment is running), and to simplify and streamline the remaining steps. The name Single-Minute Exchange of Dies comes from the goal of reducing changeover times to the "single" digits (i.e. less than 10 minutes).

A successful SMED program will have the following benefits:

1. Lower manufacturing cost (faster changeovers mean less equipment down time)
2. Smaller lot sizes (faster changeovers enable more frequent product changes)
3. Improved responsiveness to customer demand (smaller lot sizes enable more flexible scheduling)
4. Lower inventory levels (smaller lot sizes result in lower inventory levels)
5. Smoother startups (standardized changeover processes improve consistency and quality)

Application of SMED technique is illustrated in the following figure and table:

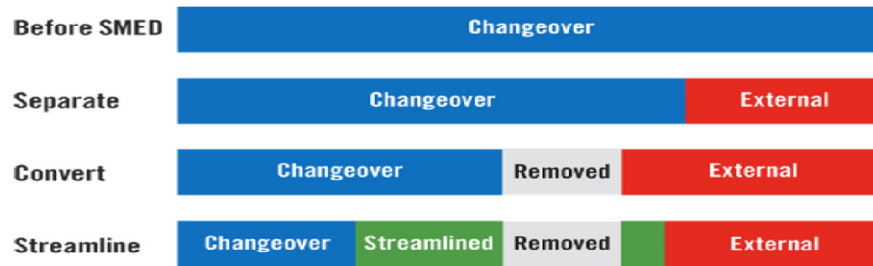


TABLE 1: SMED Optimised Values

S No.	Die A to B	Cycle time: 93:15:00	Cycle time: 36:00:00	(Including allowances)	No. of Operators : 2
	Job Description	Absolute time (min)	Optimized time	Suggestions	Work distribution
1	Unlocking allen bolts using allen key	4:29:00	1:00:00	Use impact wrench. eg:-Craftsman C3 19.2 Volt cordless (406.74 NM)	A -B on each pillar
2	Displacing right support (Locating and fastening)	2:14:00	2:20:00	Club activity 2&3 (one operator for one support)	A -B on each support
3.	Displacing left support (Locating and fastening)	2:34:00			
4.	Loosen pillar base bolts and open top nut	4:47:00	1:00:00	Use impact wrench. eg:-Craftsman C3 19.2 Volt cordless (406.74 NM)	A - B for each pillar
5.	Removal of H shaped pivots and placing it on the rack	2:52:00	Eliminate	Don't keep H pivots fastened on the die if you have to ultimately remove it.	
6.	Goes to bring overhead crane controller	0:32:00	0:32:00		A
7.	Goes to bring eye bolts and fastens it in the die	4:17:00	Eliminate	A)Keep the eye bolts near the work station. B) keep the eye bolts fastened on the die.	
8.	Goes and brings belt	3:29:00	Eliminate	Keep the belts near the work station	B
9.	hooks belts to the die		0:10:00		
10.	Lifts the die up	5:12:00	0:45:00	Modify lifting Mechanism (make belt parallel to pillars) to facilitate easy removal and reduce thread wear.	A - lifts B - holds
11.	Places the die on the rack	2:40:00	2:40:00	A - lifts B - holds	
12.	Unhooks the clamps and removes eye bolts	0:35:00	Eliminate	No need to remove (keep as is)	
13.	Hooks the clamp on the new die and starts lifting	2:45:00	2:45:00		A - on crane B -clamping

S No.	Die A to B	Cycle time: 93:15:00	Cycle time: 36:00:00	(Including allowances)	No. of Operators : 2
	Job Description	Absolute time (min)	Optimized time	Suggestions	Work distribution
	the die				
14.	places the die on the trolley	1:11:00	Eliminate	Keep the die directly on the working station surface	
15.	Unhooks the clamps and cleans the die	0:46:00	Eliminate	Keep the die directly on the working station surface	
16.	Removal of H shaped pivots and fastens the eye bolts and starts lifting the die	3:56:00	Eliminate	Keep the die directly on the working station surface	
17.	Takes the trolley back to the storage location	1:07:00	Eliminate		A - on crane B - handling
18.	Brings the die to workplace		1:07:00		
19.	Worker comes back		Eliminate		
20.	starts placing the die on the working table		1:40:00	Eliminate	
21.	Removes the clamps and unscrews the pillars bolts using ratchet	1:53:00	0:30:00	Use impact wrench. eg:-Craftsman C3 19.2 Volt cordless (406.74 NM)	A - B for each pillar
22.	Shifts the pillars at the specified locations	1:03:00	1:03:00		A - B for each pillar
23.	Starts tightening the allen bolts	0:32:00	Eliminate	Idle time	
24.	Finishes fastening and starts lifting the die	1:12:00	1:12:00		A - B for each pillar
25.	locates the die to place in the pillars	1:48:00	0:50:00	Use taper at the top of pillars so that die is easily located	A - on crane B - handling
26.	Removes the clamps, eye bolts and goes to place the belt and comes back	0:41:00	Eliminate	No need to remove (keep as is)	
27.	Takes the overhead crane back to its position	1:56:00	1:56:00		A - on crane
28.	Places the top nut on the die(pillars) and fastens the allen bolts and starts locating the backup angles	6:49:00	3:00:00	Use impact wrench. eg:-Craftsman C3 19.2 Volt cordless (406.74 NM)	A - B for each pillar
29.	Finishes locating and starts tightening the allen bolts and adjusts the inclination of backup plates.	20:49:00	3:00:00	A) Remove one of the backup plates. B) Standardize the bolts used. C) Use power tool. D) Modify backup plates	A - on support1 B - on support 2
30.	Checking the m/c for required bend angle	1:11:00	1:10:00	merge both activities	A - on m/c B - on die
31.	Oiling	1:09:00			



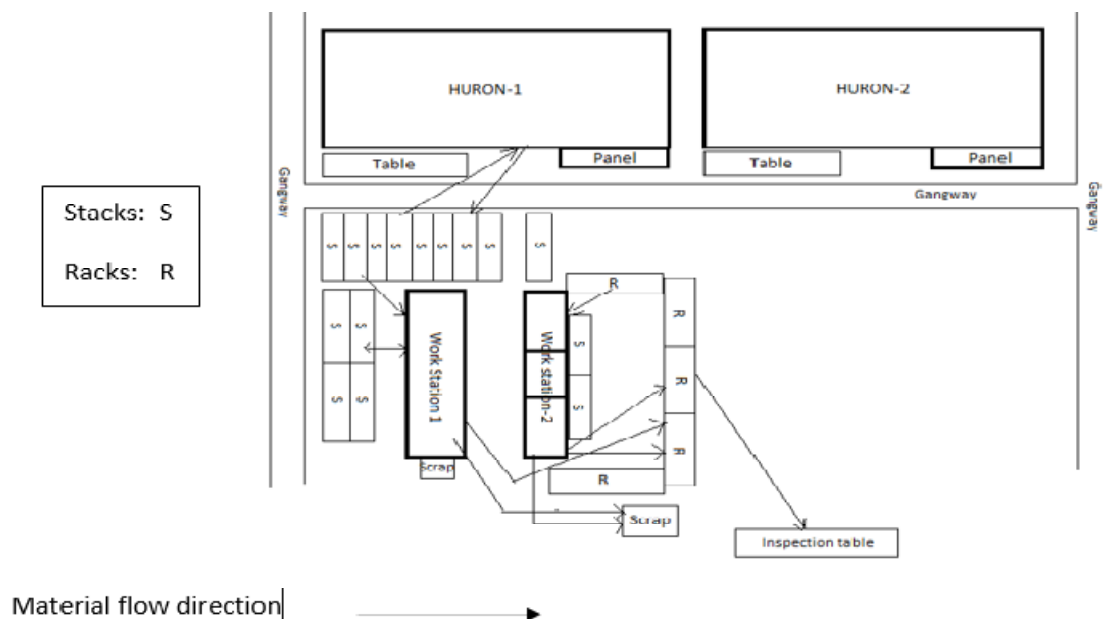
S No.	Die A to B	Cycle time: 93:15:00	Cycle time: 36:00:00	(Including allowances)	No. of Operators : 2
	Job Description	Absolute time (min)	Optimized time	Suggestions	Work distribution
32	Places the job on the die and inserts it into the chuck	4:30:00	4:30:00		A
33	Bending operation completed	3:30:00	3:30:00		A
34	Marks centerline	0:30:00	0:30:00		B
35	Removes the job and measures for required dimensions	0:30:00	0:30:00		B

### 5. LAYOUT IMPROVEMENT OF DEBURRING SECTION (APPROACH TO PROBLEM 2)

Burrs are most commonly created by machining operations, such as grinding, milling, engraving or turning. These are removed with the help of a deburring tool in the process called 'deburring'. There is improper material flow and huge cycle time involved, to overcome this new layout for the deburring shop was proposed.

Approach towards problem solving:

1. Study the current layout which is installed on the shop floor.
2. Analyze the current man and material movements involved.
3. Collect the necessary data required to determine the various parameters of new or modified layout.
4. Determine various alternatives for the layout and focus on shortlisted ones.
5. Determine feasibility and expandability of suggested layout for future.
6. Implement and improve continuously

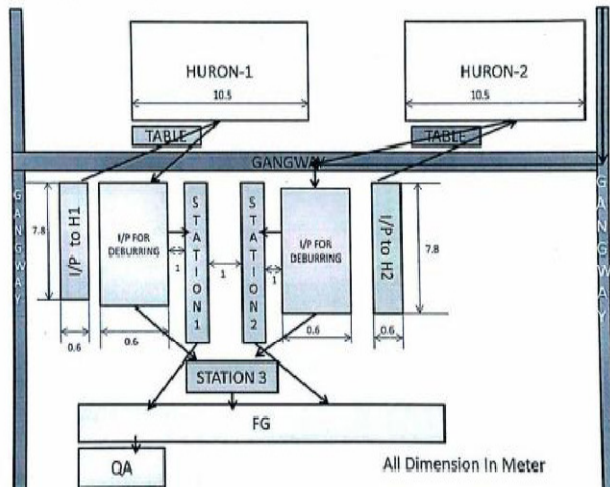


**Fig. 1. Current Layout for Deburring Section**

Random man and material movement was observed and there were chances of accidents due to Multidirectional material flow. The space available for worker movement is very less and congested. The inspection table and storage

racks are placed improperly. To eradicate such deficiencies, a new layout for deburring section is proposed. The comparison for both proposed alternatives are shown in Table 2.

Deburring Area Layout – Proposal 1



Deburring Area Layout – Proposal 2

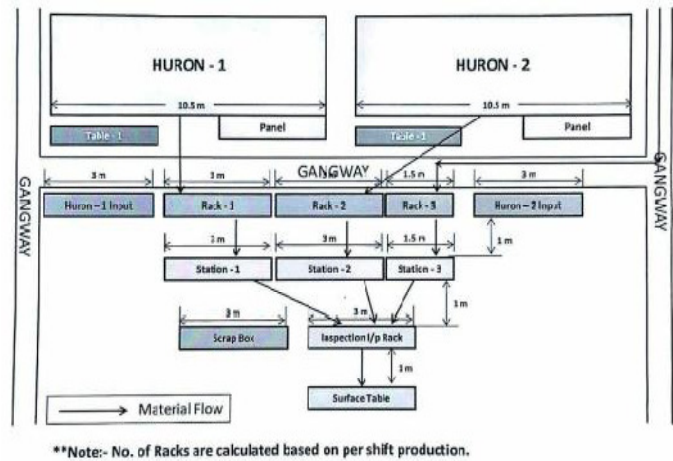
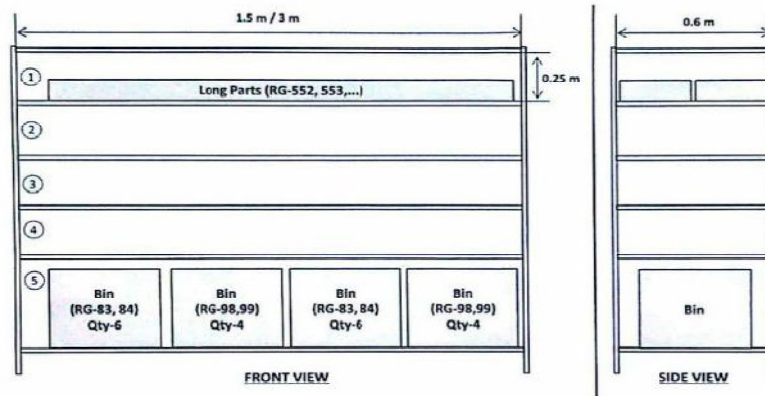


Fig. 2. Proposed Layout for Deburring Section Area: 91 sq meters (for both layouts)

TABLE 2: The Pairwise Comparison of both Proposed Layout Alternatives

Sno:	DEBURYING AREA LAYOUT-1	DEBURYING AREA LAYOUT-2(preferred)
1.	Multidirectional material flow	Unidirectional material flow
2.	More man and material movements	Less man and material movements
3.	More chances of accidents	Less chances of accidents
4.	Difficult expansion( future scope)	Easy expansion
5.	New racks are required to be purchased	Current resources can be utilized

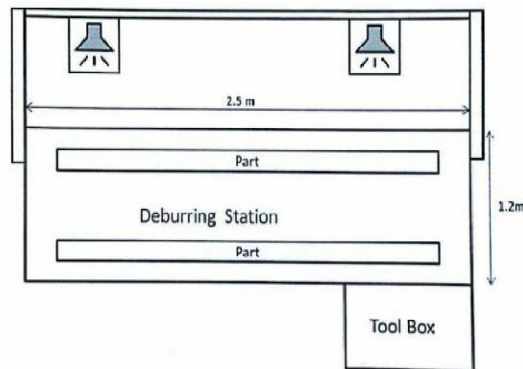
### Rack Design



- ✓ No. of Racks are calculated based on per shift production.
- ✓ No. of Rack:- 3m = 2 & 1.5m = 1
- ✓ No. of Shelf's:- 3m = 6 & 1.5m = 3
- ✓ Rack Capacity:- 3m = 24 parts in 2 racks (considering single part stacking)  
1.5m = Approx. 20 parts in 4 bins

Fig. 3. Proposed Design for Storage Racks

### Deburring Station – Proposal 1



### Deburring Station – Proposal 2

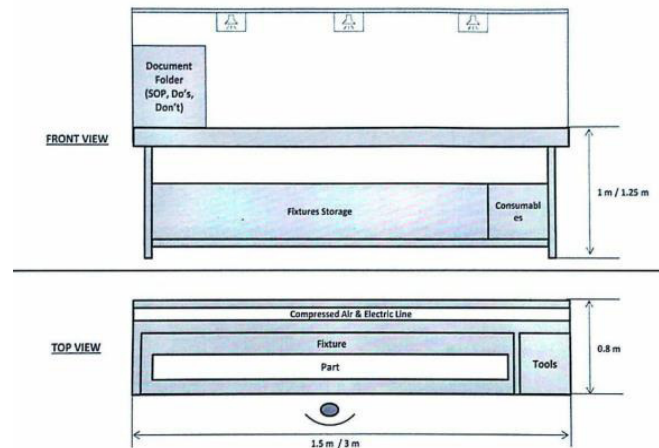


Fig. 4. Proposed Design for Deburring Workstations

## 6. CONCLUSION

It has been observed that the application of SMED technology saves a huge amount of non value adding time which eventually increases the productivity substantially. The combination of necessary processes and approach to decrease the idle time between or during operations definitely adds up to the profit of the firm. In a manufacturing sector like aviation where the cost is a major parameter, such implementation brings out the better output. The modifications in layout and designing the workplace according to work profile and operators improves the productivity as well as profit.

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# Implementation of JIT Purchasing in Make-to-Order Strategy

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**Abstract:** Customization of products is becoming more popular in recent years. To compete with other manufacturers and providers, customer satisfaction is very crucial. The objective of Build to order (MTO) Supply Chain is to meet the requirements of individual customers based on their interest and needs. These products should be delivered in short period of time and at reasonable price. One of the very important parameter is waiting time for the customers. For that Inventory purchasing is one of the very critical decisions in Build to Order supply chain. Just-in-time (JIT) inventory purchasing is a strategy in Supply chain for managing and organizing the inventory purchasing functions. There must be proper coordination between purchasing and manufacturing department of the firm. This paper investigates the effect of Implementing JIT purchasing in MTO strategy. This leads to smooth flow of inventory, decrease in leadtime, low order cost, small lot size ordering, perfect quality, low overhead cost (nonvalue adding activities), effective and efficient transportation and better material handling systems. In this paper some benefits, guidelines, limitations and future scopes are also identified in this paper that need to be studied further based on examination.

**Keywords:** Make to Order, Build to Order, JIT Purchasing, customization of products

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## 1. INTRODUCTION

In the current globalization and competitive environment companies have to deal with many product objectives such as quality, price, service, flexibility etc. To remain ahead of the competitors, customer satisfaction is very necessary. In the current time the attraction towards customized product is also increasing rapidly. Make-to-order strategy provides customized products and services according to the customer orders. One of the first successful Make-to-Order (MTO) companies was Dell Computers. Dell gained benefit from providing customized computers using internet as a link between customers and company and achieved good results. The main problem related with MTO is that firms are not sure what and how much of different Inventories and parts to keep in stock so that they can provide better services to the customers and simultaneously reduce the Inventory costs.

Most of researchers have taken into consideration the development of individual units of the supply chain like purchasing, manufacturing, distribution, delivery etc. These individual units are evaluated based on their internal efficiency, not by their role and coordination with other units in Supply Chain. The performance of the complete supply chain may not be at the level of the individual units in the chain. It is possible that each individual unit is performing well but the performance of whole supply Chain is poor. That is because of poor coordination and information sharing between different units. Inventory Purchasing is very important part of the SC.

Manufacturing and assembly take about only one-third of the total time of the make-to-order supply chain. The rest of the time is spent on ordering and purchasing components, installing and waiting. So the problems that occur at the interference between different units of the chain also need to be examined properly.

This paper is structured as follows. Section 2 reviews the literature on make to Order and JIT purchasing. Section 3 gives overview of Make to Order and identifies the gap in this strategy. Section 4 presents the JIT Purchasing and its guidelines to implement and analyse the results. Finally, Section 5 gives conclusions and the limitations of the research and method.

## 2. LITERATURE REVIEW

Jonni Jahnukainen, Mika Lahti (1999) investigated efficient purchasing methods in Make-To-Order (MTO) supply chain. They identified the problems related to purchasing in MTO and suggested some guidelines for efficient purchasing practice.

Funda Sahina, E. Powell Robinson Jr (2004) observed vendor-manufacturer relationship in make to order supply chain. Their objective was to measure the benefits from information sharing and coordination. The cost reduction was significant by implementing the integrated supply chain rather than traditional supply chain.

J. González-Benito and I. Suárez-González (2001) examined different effects of the variables related to the

Just-in-Time (JIT) purchasing practices in interacting organizations in Spanish auto components manufacturers. It helps in understanding the dynamics of the JIT purchasing and also points out that JIT purchasing strategy requires certain attributes from suppliers.

Reck et al.(1992) examined the need of integration of different functions in the organization.By interviewing the purchasing and materials management heads, it was clear that purchasing and materials management not just assure the continuous flow of resources into the organisation but it was very important component to the Development of a firm's competitiveness. purchasing and materials management activities are followed by a series of simultaneous activities in complete supply chain.

Alonso and Frasier (1991) Researched on JIT planning and critical success factors. They told that management should also apply and encourage JIT in planning and managerial activities in addition to the manufacturing plant. The performance of the firm increases by reducing the management delays. He also stated that benefits gained by application of JIT principles are better if the lifecycle of the product is shorter.

Fawcett and Scully (1995) investigated the strategies for JIT purchase along with contingency environment by survey based methodology. They investigated it in planning, organizational support and implementation. Advised that JIT purchasing strategies shows appropriate response to global competitive environment and it provides significant good impact on performance improvement with sufficient planning and support are provided.

Chen and Chen (1997) examined a case study of a Chinese automobile company and presented a survey of 50 suppliers to understand the current status of manufacturer-supplier relationships based on JIT principles. They suggested some improvements such as creating partnership between manufacturer and supplier, reducing the supplier base, supplier should be selected in JIT context and its performance should be evaluated continuously, development of quality function, reducing the lot size and constructing the required infrastructure. Training and education is also emphasized in JIT Purchasing.

D.Garg (1997) conducted a case study of an Automobile Company in India which had adapted JIT Purchasing. It is observed that this company is satisfying most of the JIT purchasing and supplier evaluation criteria and they are given good weightage. The company performance was good and competitive in spite of the old machinery by applying JIT principles. It is also observed that JIT purchasing is giving good contribution to company performance.

### 3. MAKE-TO-ORDER (MTO)

MTO is a pull type system which allows customization of products to some extent. Make-To-Order Supply Chain can be described as a strategy that produces quality products or services according to the requirements of the customers at reasonable prices, within a short time period proper planning and coordination and using proper information sharing medium such as the Internet to integrate the chain. In customization of the product, speed and flexibility are very important criteria.

So the main objective of a BOSC strategy is to fulfil the requirements of individual customers. MTO provides a flexible and responsive technique that enables companies to provide the products that customers have chosen according to that need and interest. MTO reduces the dependence on forecasting, safety stock and working capital. MTO can result in effective cost advantages by reducing the inventory, expediting etc required to customize products or services. MTO is more efficient. Finished goods do not remain stored in the system as it pulls the materials according to predefined customer orders.

The manufacturer can react on time according to the market behaviour and customer demand in MTO. For this purpose the main requirement of the manufacturer is the real-time information from the customer and market in order to achieve the target. The main objectives of MTO are responsiveness and flexibility. However, the demands of customers are always changing. So it has some limitations related to such customer behaviour in speed and flexibility.

#### 3.1 Customization of Products

In modern times many companies try to offer consumers the customized products according to the customer demand. This trend can be related to cars, bikes, clothes, home decorative items etc. Providing customized products to the customers, builds the feeling of satisfaction. It also gives you a competitive advantage over other suppliers selling similar products. Customers feel like their own products. It sounds great but personalization is not easy to implement. Customers are also ready to pay more for their customized product.

#### 3.2 Gaps in Build to Order

One of the very important considerations is delivery time. The process should be planned so that the waiting for customers should not too long. Customers tend to turn off by the waiting. For that the Inventory purchasing and process planning play a very important role.

The problems related with inventory purchasing are

- slow inventory turnover
- improper timing and delay of critical components

- poor punctuality in delivery process
- Improper quality of the inventory

In earlier days the inventory purchasing has been done primarily based on buying it at the lowest possible price. But now the role of purchasing has increased. So this method needs to be updated or changed. Buyer should spend more time on supplier cooperation and coordination & less time on price negotiations and miscellaneous not value adding works.

Purchasing should be well disciplined to improving overall productivity and eliminating waste. These benefits cost effective manufacturing and delivery of quality parts at the right time utilizing the least resources. That facility space reduction is one of the very important elements of costs reduction. Physical storage space costs and material handling costs are usually neglected in the classical economic order quantity models.

Efficient purchasing practices should include

- suppliers controlled as own manufacturer,
- special arrangement for critical components,
- modern purchasing practices.

#### **4. IMPLEMENTATION OF JIT PURCHASING**

JIT purchasing refers to the frequent deliveries of small lot sizes of inventories exactly at when they needed in the process. It facilitates reduction of raw materials. JIT purchasing focuses on improving quality, flexibility and service level from suppliers by building a buyer-supplier long-term relationship based on mutual trust and services.

JIT purchasing includes

- low order cost
- small lot
- size ordering
- very few suppliers
- perfect quality
- quality inspection
- preventive maintenance programs
- low overhead cost (non value adding activities) and
- Effective and efficient transportation and material handling systems.

##### **4.1 Supplier selection process**

Suppliers are selected based on geographical locations, product qualities, delivery time etc. Suppliers which can provide right quantity and right quality at the right time has

to be selected. It leads to benefits such as lead time reduction better quality control and TQM. In JIT purchasing there are few suppliers with long term contract. Proper coordination between buyer and supplier is an important key to the success of JIT Purchasing.

##### **4.2 Training of the employee**

Employee involvement is very necessary in JIT implementation. Employee training and education is very important for that. Employees can be divided into different groups because different employees require different training. Some require general training which includes basic concepts and principles while some employee require technical education which includes adequate knowledge about specific processes.

##### **4.3 Information Sharing & Technology Adaptation**

Wireless communication plays a major role in this system. For success of this process Information sharing technology plays a major role. Lack of information sharing and coordination causes mismatches and leads to misunderstandings between various departments or between buyer and supplier.

There should be provision for online information about level of customization and standard products available to the customers. Customers should be able to place or modify order online and also able to track the situation of the product with expected delivery time. It helps in determining and planning the shipping schedule, inventory planning, resource planning, capacity, price etc. It also helps in determining the demand pattern of customers.

In warehouses Radio frequency identification (RFID) should be used. It is a technology which monitors inventory level in the warehouses and can be programmed to place order itself according to the need. It increases accuracy and efficiency of the system. *Other online communication such as EDI and EFT* has to be used. Lastly the process should be evaluated time to time.

#### **5. CONCLUSION**

Make to Order needs good purchasing strategy. JIT Purchasing results in better timing of the components and lower inventories. The study shows that a MTO strategy affects the performance through its influence at the downstream of the supply chain with customers while a JIT purchasing affects the upstream. Study shows that MTO strategy is more effective with JIT purchasing than traditional purchasing techniques in most of the cases. JIT Purchasing directly reduces the Inventory holding cost and also helps in quality development program because it focuses on first time right quality.

But some Potential Risks are also associated with it such as It is necessary to find suppliers those are capable to supply

materials quickly with limited prior notice. Sometimes while ordering small quantities of materials, suppliers minimum order policies may cause a problem. Employees are also at a risk of precarious work when employed by a company which utilizes JIT technique. It requires great flexibility. Still many organizations use traditional purchasing practice. It is necessary to implement modern purchasing strategy in them and evaluate it. So in future more research can be done to strengthen buyer-supplier relation. It is also required to create a hybrid purchasing method to take advantage of opportunistic cost sometimes.

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# JIT Implementation in Service Sector

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**Abstract:** A simple definition of JIT is to produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricate parts just in time to go into subassemblies, and purchase parts just in time to be transferred in to fabricated parts. The first basic principle involved in JIT production approach is the elimination of waste. In a JIT system, waste is defined as anything associated with the production process that does not add value to the product. Thus, waste includes quality defects, inventories of all kinds, time spent to move material and time spent in setting up the machines. For this purpose, JIT uses some elements to be followed. This paper describes some of those elements & their benefits in the service sector.

**Keywords:** Just in time (JIT), service sector, JIT elements, JIT implementation

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## 1. INTRODUCTION

JIT philosophy is based on simple idea that wherever possible no activity should take place in a system until there is a need for it. The present idea of JIT was developed by Toyota's Vice President Taichi Ohno. Initially this approach was not known as JIT but as "Toyota Production System" because of its source of origin. Ten years after the introduction of the new production system, Toyota successfully implemented this technique across the company. Toyota motor company of Japan, the originator of JIT philosophy, is the leading automobile manufacturer in the world. Its products are well known for their quality. To implement JIT in service sector, it is needed to apply manufacturing style of thinking to services. Highly automated and controlled conditions are to be generated in providing services to reduce human element like the assembly line of a car. Implementation strategy will almost be the same for all types of service organizations with slight modifications depending upon the nature of service organization.

## 2. LITERATURE SURVEY

**Cem Canel et al. (2000)** shows similarity and differences in services and manufacturing sectors. The study suggested various areas for improving performance in service sector and proves that various JIT techniques can also be implemented in service industry.

**Vikas Panchal et al. (2012)** identified various JIT elements in service sectors (banking) which are mainly organization policy, team work, employee training, communication & information sharing, job satisfaction, employee feedback & suggestion, quality circles, technical supports, ergonomics design, customer satisfaction etc. It shows that implementation of JIT in banking increase value of bank by reducing inventory & communication gap.

**Vikas Panchal et al. (2013)** identified JIT elements that are important & easy to implement in the manufacturing industries & also presented the relative importance & difficulties in implementation of JIT elements in the banking sector and verified the data with the help of ANOVA techniques. According to the study the elements which are highly important & less difficult should be implemented first.

**Qasim ali nisar et al. (2014)** used simulation model for examine the benefits of JIT elements in financial sector, banking for loan approval process & found positive results. Banks can make their loan approval process efficient & effective by adopting cellular structure. The study was quantitative study for examining the role of JIT in banking sector.

**A.S..Aradhye et al. (2014)** studied various issues regarding implementation of JIT in a service industry. The study was conducted in the pilgrimage period and it was observed that waiting period of the pilgrims was reduced to 30 minutes from 8 hours by using JIT facility.

## 3. JIT IMPLEMENTATION STRATEGY

Following 3- phase implementation strategy has been suggested in the literature:-

1. Selection of area of application
2. Establishment of task force and commitment of top management
3. Critical factors of implementation

**1. Selection of area.** Identify area of your company where JIT is to be applied. If you are a manufacturing company, don't overlook your internal service industry, the



maintenance area. If your is a service industry, look for the areas in which you can apply JIT.

## 2. Establishment of taskforce and commitment of Top management.

- To determine if a JIT program would be beneficial to the business.
- If it is determined that JIT is advisable, it is the job task force to sell the idea to top management and obtain their commitment.
- Next, the task force and management must sell the idea to all other employees.

**3. Critical factors of implementation.** In order for JIT to be successfully implemented and continue to function smoothly, a firm foundation is required. This foundation must be strong enough to support introduction of JIT concepts and to provide strength to overcome problems as they arise. Some tools like cause and effect diagram, Pareto principle for prioritizing problems, benchmarking etc. can help in the implementation of JIT. Some critical factors have been identified

1. Changing the system
2. Quality
3. Teamwork
4. Education
5. Communication.

## 4. JIT ELEMENTS IN DIFFERENT TYPES OF SERVICE SECTORS

Service Sector	JIT Elements
Healthcare sector	• Medical facilities that have the flexibility to fill prescriptions, perform tests, and treat patients without routing them from one end of the building to another.     • Availability of medicines when required instead of storing them in stores/operation theatres.     • Availability of multifunctional workforce to meet demand fluctuations.     • Reducing paperwork to save doctor's time.     • Quality- involving employees in quality aspects.
Education sector	• Just in time publishing that allows professors to choose material from a variety of sources and construct a custom made book in the same amount of time and books can be ordered at competitive prices.

Service Sector	JIT Elements
	• Just in time evaluation.     • Continuous improvement in teaching and learning.     • Teamwork in project work.     • Use of technology in teaching aid.
Construction sector	• Construction firms that coordinate the arrival of material "just as it is needed" instead of stockpiling them at the site.
Maintenance Sector	• Car repair services that can turn around customers in an hour.     • Cleaning teams that follow standard operations routines quickly.     • Reducing maintenance inventory.     • Improving material handling process.     • Involving workers in quality cycle.     • Continuous improvement.
Departmental Stores	• Multifunctional workers in departmental stores that work the cash register, stock goods, arrange displays, and make sales.     • Stores that price everything the same and simply count the number of items purchased as the customer leaves.     • Supermarkets that replenish themselves according to what the customer withdraws.
Restaurants	• McDonald's, Domino's, and Federal Express, who compete on speed and still provide their products and services at low cost and with increasing variety.     • Work cells at fast food restaurants that allow workers to be added during peak times and reduced during slow times.
Banks	• A bank can be considered as a paper or information factory that converts documents or data into useful information like bills, certificates, passbooks, checks etc. With this analogy, the bank can benefit from techniques like efficient layouts, capacity planning, line balancing, inventory control, quality control and job sequencing. Banks can use JIT to eliminate tons of unnecessary files, forms, supplies, and filing cabinets.
Mail-order Operations	• Companies can reduce backlogs, lead time for processing by applying JIT techniques by reducing lot size.

## 5. BENEFITS OF IMPLEMENTING JIT IN SERVICE SECTOR

Some major issues like quality, cost, productivity, lead-time reduction etc. which manufacturing industry face are the same in service industries also. Productivity increase is a major challenge in service industries. JIT concepts and techniques can help service industries in dealing with these issues. In the literature, the following benefits are reported/expected as a result of JIT implementation :-

- Lead time reduction
- Increase in productivity
- Reduction in cost
- Improvement in quality
- Improved service
- Improved competitive position
- Saving in labour
- Backlog reduction
- Improved material handling
- Reduction in storage space

## 6. PROBLEMS IN JIT IMPLEMENTATION IN SERVICE SECTOR

Any organization that tries to implement a new concept faces a challenge. Possible problems include :

1. **Resistance to change.** Resistance to change to implement JIT is a significant problem. It can be overcome by:
  - Education in the JIT concepts.
  - Everybody working together to take full advantage of using JIT.

It should result in the redefining duties of employees

**2. Flexible demand/Lack of accurate demand forecasts.** Dynamic demand in service organizations causes erratic forecasts. Problem is solved by making customer service agents (CSA) familiar with basics of JIT concepts. Emphasis was placed on CSAs leveling their demand by periodic reviews of their own inventory levels and needs. It became apparent that the company did not need any sophisticated forecasting system but only a good monitoring effort on part of CSAs to smooth its demand pattern.

**3. Slow response time.** Another problem faced by the company during JIT implementation was the slow response time of goods shipment by its regional warehouse. A deeper analysis of the problem revealed that it was the lack of proper communication that was giving rise to slow response time. This problem was solved by direct dialogue between

the JIT team and senior managers of all warehouses. An effort was made to make aware of the significance of their cooperation in making JIT implementation a success.

**4. Lots of investment is needed for JIT implementation.** In order to implement it properly and realize the benefits from its implementation it will probably be necessary to engage in significant business process re-engineering, which requires lots of investment. In short-term, the JIT implementation may be more expensive for the organization. However, in long term it is likely to save money due to reduced waste. To increase implementation rate, right strategy should be designed and adopted. The organizations which are benefited by JIT implementation must set as an example to improve JIT implementation rate in service sector.

## 7. CONCLUSION

Service systems are a dominant and growing collection of industries. JIT can play a major role in making service systems operate more efficiently, regardless of how much the service product is "goods" or "services". Certain service operations like materials management, paperwork operations, and administrative activities required in all business operations contribute greatly to the cost of the products. As discussed in this paper, the integration of JIT principles to these areas can help in improving these operations. In this paper certain implementation aspects, problems in the implementation of JIT and benefits of JIT applications in service operations are discussed.

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# Just-in-time Purchasing and its Implementation in Indian Industries: A Systematic Review

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**Abstract:** In the continuously changing and globalizing market companies have to compete on many parameters such as cost, quality, flexibility, availability etc.. Inventory purchasing is one of the very important decisions in the production system. Purchasing plays a major role in deciding the final price of the product. Just-in-time (JIT) Purchasing is an approach for operating and improving the purchasing function. JIT Purchasing is very powerful inventory purchasing technique in cost saving, quality improvement, reducing the lot size etc. JIT Purchasing eliminates the waste and also helps in quality improvement. This paper reviews the literature available on JIT Purchasing. Based on study, some guidelines and future study to implement it in Indian Industries are also identified.

**Keywords:** JIT Purchasing, JIT Indian Industries, Inventory

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## 1. INTRODUCTION

The first idea of J IT was created and successfully implemented by the Toyota Motor Company in Japan. Since then it's getting popular and successful worldwide. Now JIT is globally accepted technique. Many companies have successfully implemented JIT philosophy and getting good results like Dell, Toyota etc. It is helpful in the current globalizing and changing environment. The main objectives of JIT practice are elimination of waste, supplier participation and total quality control. JIT helps in Effective Material Management in the organization.

In JIT purchasing materials are provided to the production facility just when they are needed. In JIT purchasing, order small quantity is preferred. In JIT purchasing quality, timing and precision are very important. The characteristics of JIT systems are consistent high quality, small lot sizes, frequent delivery, short lead time, and close supplier ties. The JIT purchasing tries to reduce the lead time by selecting suppliers which are located close by and can deliver the inventory quickly without much prior notice. In JIT purchasing, suppliers are considered as outside partners who also contribute to the long term development of the buying organization. There is a close relationship between supplier and buyer in JIT Purchasing and they maintain stable, long term relationship.

This paper is structured as follows. Section 2 reviews the literature available on JIT purchasing in different aspects such as JIT purchasing philosophy, Buyer-Supplier relation, JIT vs. EOQ and JIT Purchasing in Indian Industries. Section 3 draws Conclusion and section 4 contains References.

## 2. SYSTEMATIC LITERATURE REVIEW

### 2.1. JIT Purchasing philosophy

An attempt has been made in this paper to review the literature available on JIT purchasing with an objective to establish a framework for improving the effectiveness of purchasing function using the application of CE. Furthermore some techniques are also offered to overcome some of the major problems of JIT purchasing. One of main future directions is the modelling and analysis of JIT purchasing system from the perspective of supply chain management. The application of information technologies such as EDI and EFT play a significant role in achieving JIT purchasing. (A. Gunasekaran, 1999)

This study investigates the changes in just-in-time (JIT) purchasing practices over time. The importance of knowledge of nine different areas of JIT purchasing activities is highlighted. Regression and bootstrapping method were used for comparison between time periods. Most of the results were similar to earlier results but the only significantly more important item was the contract provision for delivery frequency. It is found that purchasing professionals have learnt and were more familiar with JIT purchasing practices. So the problems occurring in the chain have reduced to some extent. (Larry C. Giunipero and Kishore Gopalakrishna Pillai, 2005)

The author has focused on the characteristics of the purchased products. An extensive questionnaire was carried out. The effect of seven variables- Volume, specificity, technological complexity, essentiality, fragility, variability & economic value of procured products has been tested on Spanish auto component manufacturers. Four dimensions of JIT purchasing have been distinguished-Operational,

Relational, Involvement and quality practices. Results show that companies do not get attracted the minimization of inventory cost, but they seem to be motivated by objectives such as quality, responsiveness, innovation or minimisation of circulating products. Moreover he suggested that operational JIT purchasing practices are applied to fragile and expensive products, whereas the other purchasing practices can be applied to specific and essential purchases. (Javier Gonzalez-Benito, 2002)

It's an Empirical study In Spanish auto component manufacturer. Analytical Framework to distinguish between operational practices and complementary practices is proposed. Results show that complementary practices reach higher levels of implementation than operational practices. This means purchasers tend to create a partnership atmosphere with a large number of suppliers, but JIT logistics is applied to only some of them who have good quality and reliability standards. It is also advised that suppliers with International availability tend to reach higher level of Implementation. JIT pioneering companies achieve better results than laggard companies. (Javier Gonzalez-Benito, Martin Spring, 2000)

J. González-Benito and I. Suárez-González (2001) examined different effects of the variables related to Interacting organization in the Just-in-Time(JIT) purchasing practices. It helps in understanding the dynamics of the JIT purchasing and also points out that JIT purchasing strategy requires certain attributes from suppliers. A theoretical framework is proposed and used to evaluate the relevance of a number of variables related to the organizations of Spanish auto components manufacturers. (J. González-Benito, I. Suárez-González, 2001)

## 2.2 Buyer-Supplier relation

Due to drastic changes in the purchasing selection process, this study reviews the past research and evaluates the supplier selection decision in purchasing process. Specific attention is given to the some important purchasing criteria and analytical methods used in the supplier selection process. In this study Just-In-Time (JIT) strategy and its impact on supplier selection is also presented. In JIT strategy, geographical location of supplier is clearly one major parameter. Quality, delivery punctuality, net price, capacity, facility etc. are other important parameters to be concerned. (Charles A. Weber, John R. Current and W.C. Benton, 1991)

In this paper, two Just-In-Time (JIT) purchasing models, one utilizing a few suppliers, and the other using the more conventional single supplier are examined. For single supplier, a procedure is model is developed to obtain the optimal number of suppliers and the size of the split orders. The optimal number of suppliers is found by considering

the aggregate ordering costs. (Jae-Dong Hong, Jack C. Hayya, 1992)

A survey was conducted on a sample of machinery and electronics firms. The survey involved 457 respondents from 50 plants .It analyses the performance and nature of the practices that is useful to create link between the buyer's and supplier's operations. The practices considered shows three main underlying factors which are (a)delivery synchronisation, (b) interaction on quality and (c)interaction on design. (Guido Nassimbeni, 1995)

This paper examines the requirement of integration of buyer and supplier for better implementation of JIT purchasing. A lot-splitting model for delivering small lot sizes is proposed and compared with simple JIT model. It is found that the integrated approach can provide a better and consistent cost minimizing result for both buyer and supplier over the simple JIT approach. (Daesung Ha, Seung-Lae Kim, 1997)

A model is developed to test and determine whether the use of JIT purchasing reduces logistics costs for both suppliers and buyers. The results show that JIT purchasing directly reduces costs only for buyers. However, an indirect path was found to reduce logistics costs for suppliers. Suppliers has to implement JIT manufacturing in alliance with a JIT purchasing program. So suppliers may need to adjust their manufacturing practices to benefit as well. (Yan Donga, Craig R. Carter b, Martin E. Dresner b, 2000)

Most of the researches were focused on the benefit from quality improvement or lead-time reduction in inventory models but only from purchasing point of view. However, consideration of both, the vendor and the purchaser is essential for successful implementation of just-in-time purchasing model. This paper presents an integrated inventory model to minimize the total cost by simultaneously optimizing the order quantity, lead time, process quality and number of deliveries. This integrated JIT purchasing model is useful particularly for JIT inventory systems in which the vendor and the purchaser form a strategic alliance for profit sharing. (JIN-SHAN YANG and JASON CHAO-HSIEN PAN, 2004)

## 2.3 EOQ vs JIT Purchase

In this paper Just-in-Time (JIT) purchasing and Economic Order Quantity (EOQ) is compared based on only unit total cost criteria. It is concluded that if damage cost is not taken into consideration, the unit total cost of a JIT lot size for single stage is more than that of a EOQ system. It is drawn that JIT lot-size is better than EOQ lot-size only within some range. (FuchiaoChyr, Tsong Ming Lin and Chin-Fu Ho, 1990)

In this study, the Inventory costs of EOQ and JIT purchasing have been compared.This inventory purchasing cost models is an extensionof prior methodology ofFazel

by including relevant physical distribution cost savings. An existing problem from a literature was used to compare costs. It is seen that situations where annual demand of inventory is moderately large, purchasing strategy tends to favour EOQ method. But this model lacks in dynamic cost components which is present in JIT purchasing plans. So for longer period of time JIT purchasing serves more benefits. (Marc J. Schniederjans, Qing Cao, 2000)

Here, a mathematical model has been developed for comparing the total cost for JIT and EOQ purchasing with price discount. Many parameters influence the choice of the right strategy. It is shown that at lower demand, JIT is the preferred method, while EOQ has more cost advantage for an item with a high demand. JIT may not always lead to superior cost performance and a mixed strategy can be developed to take advantage of both. But still the implementation of JIT system is advised even though inventory cost considerations because only cost may not justify the choice and other parameters such as quality & flexibility should also be considered. (Farzaneh Fazel, Klaus P. Fischer, Erika W. Gilbert, 1998)

## 2.4 Indian Context

Indian industries have not implemented the JIT approach completely due to some lack in adoption. Implementation of JIT in Indian industries is not an easy job. Currently, number of attempts has been made in some Indian industries to implement the JIT practice in working environment.

The author carried out a literature study of JIT Purchasing in Indian Industries. This paper reviews and classifies the literature available on JIT purchasing. It identifies the important attributes in JIT purchasing. An examination of the attributes was carried out in Indian environment. The relative importance of such attributes is highlighted. Some research directions are also identified which is needed to be studied. (Dixit Garg, S. G. DESHMUKH, 1999)

In this paper a study has been carried out in integrated Steel plant of India for the purchase selection. Mainly two problems have been covered- (a) Materials and vendors which can be brought under JIT Network and (b) a freight Consolidation Model (FCM) for collecting items from vendors. It is found that JIT purchase will give the more saving in total cost as compared to the larger lot size for items which falls under JIT category. Transportation and ordering costs increase in JIT purchase, but holding cost and carrying cost reduces faster than that. (R.N. Roy, K.K. Guin, 1999)

This paper studies the JIT literature to evaluate the JIT practice in India and the factors responsible for slow implementation in India are identified. A survey was conducted in 45 manufacturing industries in India. It is found that the problems for slow implementation are lack of information on JIT implementation, lack of justification for

practicing JIT, lack of assistance available from consulting firms and government bodies, lack of formal cross training program for workers, problems in maintenance time reduction, and initial high investment in layout. (V.D. Wakchaure, M.A. Venkatesh, 2006)

The author conducted a survey of 33 Indian industries. This survey highlights the difficulty in implementing JIT philosophy in Indian industries. He suggested that industries must implement JIT philosophy completely to enjoy its benefits. It may require changes in its operational procedures, production system and in many cases work culture also. Sometimes the plants layouts, relations with suppliers also have to be changed. (Bhupesh Lohar, 2011)

The author has highlighted the problems faced by Indian organisations while adopting JIT practice. The obstacles in this process are identified and divided into categories such as organisational, cultural, behavioural, operational, technological, financial and departmental obstacles. Based on study the success factors such as top management's contribution, employee training, change in work culture etc. have been suggested. (Gurinder Singh, 2013)

## 3. CONCLUSION

In this paper, an attempt has been made to review some of the literature available on JIT purchasing with the objective to understand and get more insights of the JIT purchasing and to identify future research directions in this area. Based on only cost criteria, implementation of JIT purchasing may not be feasible in many situations. So to take advantage, a combined technique can be developed and studied further. But still JIT purchasing serves many other benefits such as quality, lead-time reduction, waste reduction, efficient use of shop floor area etc. which also has to be considered.

Still it is not properly evaluated to what extent *suppliers* can benefit from JIT purchasing practice. In India, JIT purchasing is adopted by many firms. But still there are many industries which still use traditional purchasing practices due to lack of technological adoption which needs to be upgraded. Proper guidelines have to be created for Indian Industries for JIT Implementation. Use of latest technology and latest machines are also necessary in JIT success. The identified important parameters need to be studied more during JIT implementation in industries.

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SECTION – VIII  
ADVANCED AND TRADITIONAL OPTIMIZATION  
TECHNIQUES

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# Investigation of Performance Parameters on Electro Discharge Machining Using Cuckoo Search Algorithm

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**Abstract:** Electro discharge machining (EDM) is widely used non-traditional machining (NTM) process that is used for complex and precision machining. Parameter optimization of NTM processes gives high productivity in terms of machining performance in the modern industries. In this paper, a case study of EDM process is considered with the objective to enhance the performance parameters like, material removal rate (MRR), surface roughness (Ra) and a relative electrode wear ratio (REWR) are considered. Cuckoo search algorithm (CSA) is applied to the given case study. The solutions obtained using CSA are compared with the solutions obtained by previous researcher which shows the effectiveness of the considered algorithm.

**Keywords:** Cuckoo search algorithm, Electrical discharge machining, Material removal rate, Surface roughness

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## 1. INTRODUCTION

In last decades, demands of non-traditional machining (NTM) processes have been increased due to its high dimensional accuracy and capability of machining hard materials. These materials deliver a large diversity of application in today's modern industries in the fabrication of several merchandise, like aerospace, defense and automotive industries which requires material with higher strength. Electrical discharge machining (EDM) is a suitable process for creating complex geometry with higher accuracy. In this paper, EDM is considered for parameter optimization. The important performance parameters considered are material removal rate (MRR), average surface roughness (Ra), relative electrode wear ratio (REWR). The non-traditional optimization technique considered is Cuckoo search algorithm (CSA).

The rest of paper is organized as follows. Section 2 briefly reviews the literature on EDM process. Section 3 presents the proposed method for optimization of performance parameters and outcomes are described with discussion. Finally, conclusions are presented in Section 4.

## 2. LITERATURE SUREY

The broad literature reviews were held away from various available databases related to the EDM process to find the literature gap and to obtain the basic thought of the machining process. The work of Uhlmann, Piltz and Doll (2005) have reviewed the applications of micro-EDM in the area of micro mould making dies. Norliana, Solomon, Fuad Bihari (2007) have reviewed the research trends in EDM on ultrasonic vibration, dry EDM machining, EDM with powder additives, EDM in water and modeling technique for predicting EDM performances. Pecos and Henriques (2009) have attempted the Strengths-

Weaknesses- Opportunities - Threats (SWOT) analysis for the intrinsic innovations in die-EDM and estimated its impact in the manufacturing industry of mould. Garg, Singh and Sachdeva (2010) have reported a review on the future trends of EDM applications in the machining of metal matrix composites (MMC). These MMCs have found applications in the automotive, aerospace and defence equipment's. Chung et al. (2011) have discussed the techniques to enhance the micro electrical machining performance. The improved-performance of the process was expected to enhance the manufactured goods in a high-tech industry. Maradia et al. (2012) have analysed the capability of die-sinking EDM (Die-EDM) in micro level machining utilizing the primary process parameters to enhance the performance of the process. They have utilized the graphite electrode which offers efficient solution towards the micro machining. Pontelandolfo, Haas and Perez (2013) have investigated the effects of dielectric fluid on the performance of Die-EDM process using computational fluid dynamics. Hinduja and Kunieda (2013) have reviewed the models developed to simulate the different phenomena, i.e., potential models to predict current density distribution and anodic dissolution in ECM, thermal probabilistic models for the plasma arc and discharge location in EDM process. They have specified some salient applications and desirable future enhancements to these models. Talla et al. (2015) have attempted fabrication of machine alumina metal matrix composite using EDM by adding the aluminium powder in kerosene dielectric to improve the performance of the process. The result shows improvement in MRR and Ra when compared with conventional EDM process. Dewangan, Gangopadhyay and Biswas (2015) have conducted an experimental investigation to determine the influence of the machining parameters on surface integrity of EDM process. Tripathy and Tripathy (2016) have used a

combination of Taguchi methodology and Technique for order of preference by similarity to ideal solution (TOPSIS) approach to determine the optimum and significant effects of the process parameters on performance characteristics of the powder mixed EDM process. Dey, Debnath and Pandey (2017) have investigated the influence of EDM process parameters on MRR, Ra and electrode wear rate (EWR) using RSM approach during machining of Al6061/cenosphere composite. They have applied grey-based hybrid approach to obtain the optimum parameter setting of the considered process.

In this paper, CSA is applied to the continuous domain optimization problem of EDM process. Past researchers have applied RSM and GA to the considered problem to optimize the machining parameters but the solution obtained were sub-optimal. In this paper, the results obtained using CSA is compared with previous researcher results to see the effectiveness of the present approach.

### 3. CUCKOO SEARCH ALGORITHM

CSA is developed by Yang and Deb in 2010. It is based on brood parasitism of the cuckoo species by placing their eggs in the nests of other swarm birds (Yang and Deb, 2010). CSA uses foraging path that is based on the current position and the transition probability. The working principle of CSA is based on three rules (Yang and Deb, 2010; Rajabioun, 2011). (1) Every single cuckoo lays one egg and dumps its egg simultaneously in a randomly chosen nest of other host bird, (2) The nests with a high value of eggs will carry to the subsequent generation and (3) The number of the nest for host bird is fixed. To obtain the new nest position for each cuckoo, a Levy flight is executed. To generate new solutions  $x_i^{t+1}$  for the  $i^{th}$  cuckoo, a Levy flight is performed using the following Eq. (i).

$$x_i^{(t+1)} = x_i^{(t)} + \alpha S \quad (i)$$

Where,  $\alpha > 0$  is the step size which should be related to the scales of the problem of interest. In most cases,  $\alpha$  be used as unity. The product is an entry-wise multiplication. Levy flights essentially provide a random walk while their random steps are drawn from a levy distribution for large steps as given in Eq. (ii).

$$\text{Levy} \sim u = t^{-\lambda} \quad (ii)$$

Where,  $1 < \lambda \leq 3$

The value of the parameters such as probability to alien egg ( $p_a$ ) and step size ( $\alpha$ ) is varying with respect to the generation, performs a global and local search within the range of domain. In the traditional version of this algorithm the value of these parameters was fixed (Valian et al., 2013). The convergence rate of the CSA algorithm is greatly influenced by the tuning of the parameters. So, the fine tuning of the parameter is required to search out the optimal solution of the problem. It was found in the

traditional version of this algorithm that if the value of  $P_a$  and  $\alpha$  is set at high and low respectively; then it results in a considerable increase in generation. In the other case, if the value of  $P_a$  and  $\alpha$  is set at low and high respectively then the convergence rate is better but it is unable to obtain the optimum solution. Therefore, to improve the performance of the traditional cuckoo optimization algorithm the value of  $P_a$  and  $\alpha$  is varying with respect to the generation. However, these values should be reduced in final generations to obtain a fine –tune of solution vectors. The values of  $p_a$  and  $\alpha$  are dynamically changed with the number of generation as expressed in Eqs. (iii)-(v).

$$P_a(gn) = P_{a_{max}} - \frac{(P_{a_{max}} - P_{a_{min}})}{NI} \times gn \quad (iii)$$

$$\alpha(gn) = \alpha_{max} \exp(c \cdot gn) \quad (iv)$$

$$c = \frac{\ln(\frac{\alpha_{max}}{\alpha_{min}})}{NI} \quad (v)$$

Where,  $NI$  and  $gn$  are the number of total iterations and the current iteration, respectively.

The algorithm steps for CSA algorithm are given as below (Valian et al., 2013):

1. Initialize the host nest position randomly.
2. Evaluate the fitness value for the generated nest position.
3. Obtain the best egg which has highest fitness value.
4. Generate new position of cuckoos by levy flights and algorithm parameters such as step size and probability to obtain the alien egg.
5. Replace the host position randomly, if the alien egg is detected.
6. Evaluate the fitness value for new generated host positions.
7. Check the termination criterion, if satisfied move to step 4 else step 8.
8. Store results and exit the loop.

#### 3.1 Single objective optimization modelling of EDM process

The case study for EDM is taken from (Tzeng and Chen, 2013). Tzeng and Chen (2013) developed a setup to study the effect of process parameter with respect to performance parameter in an EDM machining process. Experiments were conducted by on JIS SKD 61 steel work piece using a copper (density 8.9 g/cm³) electrode tool. At the same time, for each set of cutting time of the work piece was settled

with 20 minutes. The product quality produced by the EDM is always affected by the process parameters. Thus, proper selections of the machining parameters are required. Tzeng and Chen (2013) considered discharge current ( $I$ ), the gap voltage ( $V$ ), the pulse on-time ( $t_{on}$ ), and the pulse off-time ( $t_{off}$ ) as process parameter for the EDM process respectively. The bounds of these parameters are given in Table I.

**TABLE I: Process factors and their bounds for EDM Tzeng and Chen (2013)**

Parameter	I (A) $x_1$	V (V) $x_2$	$t_{on}(\mu s)$ $x_3$	$t_{off}(\mu s)$ $x_4$
Lower bound	7.5	45	50	40
Upper bound	12.5	55	150	60

The governing equations for the performance parameters, i.e., MRR, Ra and REWR are obtained using the considered process parameters. The mathematical predictive regression models considered for performance parameters are same developed by Tzeng and Chen (2013) given in Eqs. (vi) – (viii).

$$MRR = -253.15 + 39.7x_1 + 4.277x_2 + 1.569x_3 - 1.375x_4 - 0.0059x_3^2 - 0.536x_1x_2 \quad (vi)$$

$$Ra = 31.547 - 0.618x_1 - 0.438x_2 + 0.059x_3 - 0.59x_4 + 0.019x_1x_4 + 0.0075x_2x_4 \quad (vii)$$

$$REWR = 196.564 - 24.19x_1 - 3.135x_2 - 1.781x_3 + 0.153x_4 + 0.093x_1^2 + 0.001491x_3^2 + 0.005265x_4^2 + 0.464x_1x_2 + 0.158x_1x_3 + 0.025x_1x_4 + 0.029x_2x_3 - 0.017x_2x_4 - 0.003385x_1x_2x_3 \quad (viii)$$

The considered example of EDM is taken to demonstrate the CSA for maximize the function value (MRR). To demonstrate the application and effectiveness of the CSA algorithm for single objective optimization, the corresponding computer code for the CSA algorithm is developed in MATLAB 7.12 with the following control parameters as selected for the easy convergence of the optimization problem.

Number of iteration	100
Initial number of nest	10
Number of parameter	4
$\alpha_{min}$	0.05
$\alpha_{max}$	0.5
Number of eggs per cuckoo	1
$\lambda_{min}$	1
$\lambda_{max}$	3

There are four decision variable in the given example. The ranges of decision variables (i.e. discharge current, applied voltage, pulse on time and pulse off time) are different. The process of CSA is initialized using the control parameters and random generation of initial position of cuckoo nest position. The typical results of CSA for the considered demonstrate optimization problem are in Table II and Table III respectively. The entire results of initialization and first iteration are shown for better understanding of CSA algorithm. Initially, generate a random initial nest position of each cuckoo within the range of decision variable. The nest position values obtained are {131.5526, 124.3002, 84.6560, 100.85, 125.185, 144.6864, 142.8256, 101.3358, 75.95483 and 79.11904}. The best egg present in a nest obtained is 144.6854 corresponding to the nest position  $x_1$ ,  $x_2$ ,  $x_3$ , and  $x_4$  as: 11.4218, 49.80756, 139.8716 and 49.26582 respectively as shown in Table II.

### 3.2 Demonstration steps of CSA for EDM problem

**TABLE II: Results of initialization using CSA for EDM process**

No.	Initial Cuckoo nest position				Egg present in a nest or solution
	$x_1$	$x_2$	$x_3$	$x_4$	
$C_1(0)$	10.95676	52.26193	115.0378	50.39674	131.5526
$C_2(0)$	10.27566	49.2838	112.7647	52.17555	124.3002
$C_3(0)$	7.542371	47.10792	114.6563	54.5432	84.6560
$C_4(0)$	9.580159	47.65384	56.21331	40.00148	100.8500
$C_5(0)$	9.695591	54.93184	143.8197	43.39533	125.1850
$C_6(0)$	11.4218	49.80756	139.8716	49.26582	144.6864
$C_7(0)$	11.64999	53.2775	119.4859	47.23704	142.8256
$C_8(0)$	10.44803	51.03238	81.04062	59.04131	101.3358
$C_9(0)$	8.21037	53.17842	84.35456	58.64387	75.9548
$C_{10}(0)$	10.46657	54.55547	57.62294	59.16137	79.1190

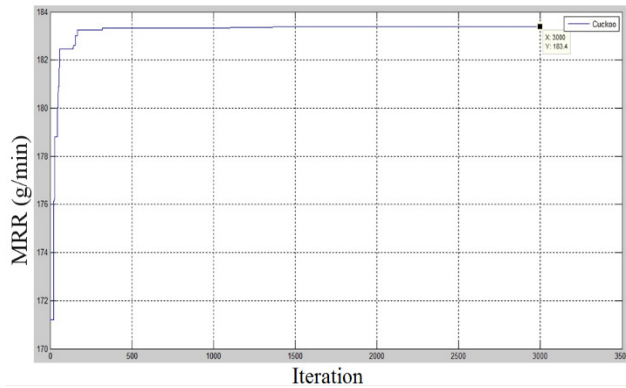
**TABLE III: Results of first iteration using CSA for EDM**

No.	Updated cuckoo nest position				Updated solution
	$x_1$	$x_2$	$x_3$	$x_4$	
C ₁ (1)	11.5736	46.5761	115.5741	54.1209	144.7066
C ₂ (1)	12.0289	54.7059	53.5711	40.6366	116.9048
C ₃ (1)	8.1349	54.5716	134.9129	45.5384	106.9339
C ₄ (1)	12.0668	49.8537	143.3993	40.9234	164.0831
C ₅ (1)	10.6618	53.0028	117.8735	41.9426	139.2168
C ₆ (1)	7.9877	46.4188	125.7740	56.4691	90.1187
C ₇ (1)	8.8924	49.2176	124.3132	53.8965	105.5584
C ₈ (1)	10.2344	54.1573	89.2227	46.3419	117.0012
C ₉ (1)	12.2875	52.9221	115.5478	59.0044	133.8525
C ₁₀ (1)	12.3244	54.5949	67.1186	40.6889	131.7671

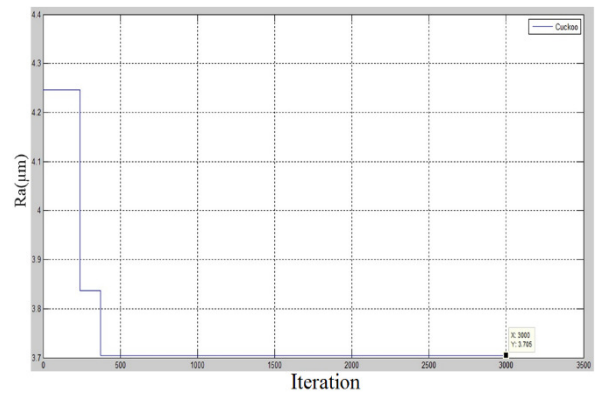
These positions of cuckoo nest position are updated using adjusting factor step size ( $\alpha$ ) and probability of worst nest. To improve the performance of the CSA algorithm in the early generations, the values of  $p_a$  and  $\alpha$  must be big enough to enforce the algorithm to increase the diversity of solution vectors. The value of  $p_a$  and  $\alpha$  obtained are 0.992 and 0.4886 respectively. Initially all cuckoo got detected by host birds and they replaced this nest position with new nest position. The new nest positions obtained are shown in Table III using Eq. (i). The updated nest position values obtained are {144.7066, 116.9048, 106.9339, 164.0831, 139.2168, 90.1187, 105.5584, 117.0012, 133.8525 and 131.7671}. The best nest position for the cuckoo obtained at the end of iteration is 164.0831 with respect to 12.0668, 49.8537, 143.3993 and 40.9234 variable respectively. This step is the end of the first iteration and process will be continued till the termination criterion satisfied. All results are stored in separate array at the end of iteration and final results are obtained.

### 3.3 Parameter optimization for EDM process using CSA

The same EDM problem is considered for process parameter optimization using CSA. The results for MRR, REWR and Ra obtained are shown in Fig. 1, Fig. 2 and Fig. 3 for the EDM process at different iteration respectively. The effectiveness of CSA optimization is measure by using equation (iv) - (vi). Table IV shows EDM results for MRR, Ra and REWR through CSA which are obtained 183.37 (g/min), 3.7051 ( $\mu$ m) and 0.0001 (%) respectively. The computational time of CSA algorithm for MRR, Ra and REWR results are 2.11 sec, 2.647 sec and 2.55 sec respectively. These result when compared with the previous researcher (Tzeng and Chen, 2013) results for RSM and BPNN/ GA, it is found better. The corresponding optimum process parameters for MRR, Ra and REWR obtained through CSA are shown in Table V for the EDM process respectively.



**Fig. 1. MRR result for EDM using CSA**



**Fig. 2. Ra result for EDM using CSA**

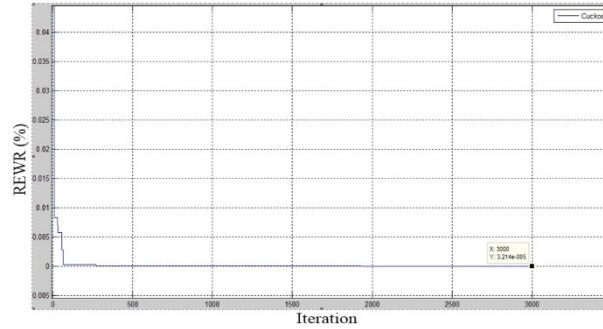


Fig. 3. REWR result for EDM using CSA

TABLE II: Comparison of CSA results for EDM

	MRR (g/min)	Ra( $\mu\text{m}$ )	REWR (%)
RSM (Tzeng and Chen, 2013)	157.39	7.83	7.63
BPNN/GA (Tzeng and Chen, 2013)	159.70	7.04	6.21
CSA	183.37	3.7051	0.0001

The corresponding optimum process parameters for MRR, Ra and REWR obtained using CSA are shown in Table V for the EDM process. Optimality of this solution can be confirmed with the help of the graphs, depicted in Figs. 4(a)-(d), showing the dependence of the objective functions MRR, Ra and REWR in Eqs. (vi), (vii) and (viii) respectively. The variations of the process parameter (discharge current, gap voltage, pulse on time and pulse off time) with respect to MRR, Ra and REWR are shown in in Figs. 4 (a)-(d) respectively.

TABLE III: Optimum process parameter for MRR, Ra and REWR using CSA

Parameter	Discharge current (A)	Gap voltage (V)	Pulse on time ( $\mu\text{s}$ )	Pulse off time ( $\mu\text{s}$ )
MRR (g/min) (183.37)	12.5	45	133.05	40.0016
Ra ( $\mu\text{m}$ ) (3.7051)	7.591	46.896	51.395	60
REWR (%) (0.0001)	12.5	45	105.385	46.635

#### 4. CONCLUSIONS

The results obtained using CSA for the considered case study on EDM process is better compared to the results of the previous researcher for MRR, Ra and REWR. The MRR which is obtained using CSA is increased from 157.39 gm/min to 183.37gm/min. The performance parameter Ra obtained using CSA is reduced from 7.83  $\mu\text{m}$  to 3.7051  $\mu\text{m}$ . Similarly the result for REWR is almost reduced to 0.0001. So the result obtained using CSA for EDM process is found effective.

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# Multi Objective Optimization of Profit of a Price Dependent Perishable Product along with a Fuzzy Freshness Parameter

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**Abstract:** A mathematical multi objective inventory model is developed. The first objective maximizes the profit of the vendor who sells deteriorating and price sensitive perishable products. The profit is treated as a fuzzy variable with the maximum profit having a membership function of 1 and has a value of 0 if the profit is below tolerance. A new factor called freshness parameter, which is fuzzy in nature, is then considered as second objective. This factor indicates the quality perception from customer's perspective. This parameter has a membership value of 1 when the cycle time is less than  $T_1$  and has a value of 0 when the cycle time more than  $T_2$  ( $T_1 < T_2$ ). Membership values, of both parameters, vary linearly. The model then optimizes the price, the cycle time which maximizes the fuzzy membership values of both the objectives. A numerical example along with sensitivity analysis is provided.

**Keywords:** Multi objective, Price dependent demand, perishable, fuzzy freshness parameter

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## 1. INTRODUCTION

Inventory management systems consisting of deteriorating items is one of the challenges faced as the items are likely to be deteriorated in a complex way. The members of the supply chain act so as to maximize their profits.

In most of the economic order quantity problems [EOQ] researchers consider demand as constant. However in reality we see that the demand for perishable goods are dependent on the price also.

The primary objective the retailer, handling deteriorating products, is to choose the right price and cycle time which maximizes the profit keeping the holding cost, ordering cost and deteriorating costs to the minimum. Also the vendor has to reduce the cycle time as far as possible in order to maintain the freshness of the products. It is a well known fact that customers try to purchase products, which have more shelf life. The more time they are held in the shelves the lesser is the quality as perceived by the customers. Thus in order to increase the good will of the vendor the products have to be kept fresh which can be achieved by reducing the cycle time.

In this paper both objectives, net profit of the retailer, freshness parameter of the products, are treated as fuzzy variables and a solution is found which maximizes the both the objectives.

## 2. LITERATURE OF INVENTORY DECISION PROBLEMS

Sana, S.S., Goyal, S.K., Chaudhuri, K.S. (2004) have derived a production-inventory model in which, the optimal number of production cycles, of a deteriorating item, with a linear time-varying demand is determined. Later Mukhopadhyay, S., Mukherjee, R.N., Chaudhuri, K.S. developed a Joint pricing and ordering policy for a deteriorating inventory (2004). Hesham K. Alfares, Ahmed M. Ghaithan (2016) have studied an inventory model for a deteriorating product where the demand of fresh products is considered as a random variable with known probability distribution. Bellman and Zadeh (1970) introduced max-min operator. Mamdani.E.H. and Assilina (1975) extended the work of Bellman and Zadeh's (1970) paper in developing fuzzy algorithms for complex systems and decision processes. T. Takagi, M. Sugeno (1985) worked on fuzzy systems whose output membership functions are either linear or constant unlike Mamdani where output is a fuzzy set. Hans-j. Zimmermann (1976) provided an approach to solve fuzzy problems. Ata Allah Taleizadeh, Mahsa Noori-daryan, Leopoldo Eduardo Cárdenas-Barrón(2015), developed a 2 level VMI model in which both raw materials and finished product deteriorate. In this model they assumed demand to be a linear function of price, used Stackelberg approach. V.Bapi Raju, G.Rambabu,(2017) also used price dependant demand to optimise various parameters in a two level supply chain.



### 3. METHODOLOGY

#### 3.1 Problem Definition and Solution Approach.

Retailers purchase the deteriorating products from vendors. It is assumed that the products deteriorate at constant rate. The retailers then sell the deteriorating product at a higher price. Here the demand is assumed to be a liner function of the price. Under these conditions it is required to find the maximum profit of the retailer. ie the price and the cycle time are determined which would give the maximum profit.

Then a second objective is considered which maximizes the freshness of the finished product. The lower the holding time the higher is the freshness. Freshness is considered as fuzzy parameter with a value of 1 when the cycle time is below  $T_1$  and with a value of 0 when the cycle time is above  $T_2$  ( $T_1 < T_2$ ). The maximum profit of the retailer is now is treated as a fuzzy variable having a value of 1 when the profit is equal to maximum profit ( $TP_{max}$ ) and value 0 if the profit is below  $TP_{max} - TP_{tol}$  where  $TP_{tol}$  is the tolerance limit of the profit. Finally a solution is found which maximizes both the objectives.

#### 3.2 Assumptions

- Lead time is zero
- Shortages not permitted.
- Demand is price sensitive and constant
- The deteriorated items are removed from the system and are not replaced. This involves some cost.
- The rate of deterioration is constant.
- A single item is considered

#### 3.3 Notations

- $I_r(t)$  Inventory level of retailer as a function of time
- $Q_r$  Order quantity of the retailer
- $H_r$  Holding cost of the retailer
- $O_r$  Ordering cost of the retailer
- $C_r$  Purchasing cost of the retailer
- $D_{tr}$  Deterioration cost of the retailer
- $S$  Retail price (decision variable)
- $\alpha$  Deterioration rate of the finished material
- $t$  Time
- $Dr(S)$  Demand of the item as function of  $S$
- $Dr'$  First derivative of Demand function
- $Dr''$  Second derivative of Demand function

- $T$  Replenishment cycle of the product (decision variable)
- $TP(T)$  Total profit as a function of time
- $TP_r$  Total profit of the retailers/unit time
- $TP_{max}$  Maximum profit without considering the freshness parameter
- $TP_{tol}$  Tolerance limit of the profit/unit time
- $FP(T)$  Freshness parameter as a function of time
- $T_1$  Cycle time below which the freshness parameter is 1
- $T_2$  Cycle time above which the freshness parameter is 0 ( $T_1 < T_2$ )
- $TP_r^*$  Optimum total profit of the retailers/unit time
- $S^*$  Optimum selling price
- $T^*$  Optimum cycle time

#### 3.4 Determining the Optimum Profit of the Retailers.

**Step 1:** Determining the total profit of the retailers

The variation of the retailer's inventory w.r.t time is given by

$$\frac{dI_r}{dt} = -\alpha \times I_r(t) - Dr(S) \quad 0 \leq t \leq T \quad (i)$$

Using the boundary condition  $I_r(T) = 0$  and solving

$$I_r(t) = \frac{Dr(S)}{\alpha} (e^{\alpha(T-t)} - 1) \quad 0 \leq t \leq T \quad (ii)$$

Substituting  $t=0$  in (2) Order Quantity  $Q_r$  is obtained.

$$Q_r = \frac{Dr(S)}{\alpha} (e^{\alpha T} - 1) \quad 0 \leq t \leq T \quad (iii)$$

Total holding cost of the retailer is given by

$$\int_0^T H_r \times I_r(t) dt = H_r \left[ \frac{Dr(S)}{\alpha^2} (e^{\alpha T} - 1) - \frac{Dr(S) \times T}{\alpha} \right] \quad (iv)$$

Total purchasing cost is given by

$$\frac{C_r \times Dr(S)}{\alpha} (e^{\alpha T} - 1) \quad (v)$$

Total deterioration cost is given by

$$\int_0^T D_{tr} \times \alpha \times I_r(t) dt = D_{tr} \left[ \frac{Dr(S)}{\alpha} (e^{\alpha T} - 1) - Dr(S) \times T \right] \quad (vi)$$

Total Profit of the retailers/unit time is obtained by subtracting total cost from total revenue

$$TP_r = S \times Dr(S) - \left( \frac{O_r}{T} + H_r \times \left[ \frac{Dr(S)}{\alpha^2 \times T} (e^{\alpha T} - 1) - \frac{Dr(S)}{\alpha} \right] + \frac{C_r \times Dr(S)}{\alpha \times T} (e^{\alpha T} - 1) + D_{tr} \times \left[ \frac{Dr(S)}{\alpha \times T} (e^{\alpha T} - 1) - Dr(S) \right] \right) \quad (vii)$$

Setting the first derivative of profit function of the retailers w.r.t S to zero

$$\frac{\partial TP_r}{\partial S} = 0 \quad (viii)$$

Setting the first derivative of profit function of the retailer w.r.t T to zero

$$\frac{\partial TP_r}{\partial T} = 0 \quad (ix)$$

Equations (viii) and (ix) are solved to obtain optimum values of  $S^*$  and  $T^*$ . These optimum values maximize the function only if the function is concave. The function will be concave if the hessian matrix of the function is negative definite i.e. the first leading principal minor of hessian matrix is negative and the second leading principal minor of hessian matrix is positive.

### 3.5 Determining the freshness parameter

Freshness parameter is a linearly varying function having a maximum value of 1 when the cycle time is  $\leq T_1$  and having a minimum value of 0 when the cycle time is  $\geq T_2$ .

### 3.6 Solution Algorithm.

Step 1 ) Using Eqs (viii- ix) find  $T^*$  and  $S^*$

The corresponding Hessian matrix for the above solution is given by

$$H_2 = \begin{bmatrix} \frac{\delta^2 TP_r}{\delta S^2} & \frac{\delta^2 TP_r}{\delta S \delta T} \\ \frac{\delta^2 TP_r}{\delta T \delta S} & \frac{\delta^2 TP_r}{\delta T^2} \end{bmatrix} \quad (x)$$

Using (x) find out if this is global maximum by checking hessian matrix is negative definite. If it is not find the optimum point by searching the entire feasible region using a computer software program.

Using (vii) find the  $TP_{\max}$  Maximum profit of the retailer without considering the freshness parameter

Step 2: Determine fuzzy function of freshness indicator.

Freshness parameter fuzzy function,  $FP(T)$ , is determined as a function of cycle time. The function looks like the dotted line in the Fig.1.

Step 3: Determine fuzzy function of total profit parameter.

Total profit parameter fuzzy function,  $TP(T)$ , is determined as a function of cycle time. The function looks like the solid line in the figure1.

Step 4: Solving the final problem

Find T and S which maximize  $\lambda$  such that

$$\begin{aligned} \lambda &< \mu_1(FP(T)) \\ \lambda &< \mu_2(TP(T)) \end{aligned}$$

with non negative conditions.  $T \geq 0$ ,  $TP(T) > 0$ ,  $FP(T) > 0$

From the graph it is clear that optimal point is the one of the intersection points of the two fuzzy membership functions.

### 3.7 Numerical example

Consider an example in the food industry .The retailer buys fruits from a supplier. He then sells them at retail price to make a profit. The demand for the fruits is linear function of the price and is given by the equation

$$D_r = a - b \times S \quad (xi)$$

The following values are assumed

$a=2200, b=11, H_r = 4, O_r = 8000, C_r = 140, D_{tr} = 145$ ,  $\alpha = 0.03$ ,  $TP_{tol} = \text{Rs } 300/\text{unit time}$ ,  $T_1=2$ ,  $T_2=4.5$  .Both the fuzzy functions vary linearly.

### 3.8 Result

The optimum solution without considering the freshness parameter is obtained as follows

Solving the problem using equations (viii) and (ix ) gives  $S^* = 177.1000$ ,  $T^* = 2.2005$  and  $TP_{\max}$  (maximum profit) = Rs 2155.1/unit time.

The values of the Hessian matrix are as follows  $H_1 = -22$ ,  $H_2 = + 28,538$ . Since the hessian matrix is negative definite, this is the global maximum value.

Now the fuzzy membership functions of profit and freshness parameter are evaluated. The same are represented in Fig. 1.

If freshness parameter is also considered as an objective then optimum values would be

$S^* = 176.6617$ ,  $T^* = 2.080$ ,  $\mu_1(FP(T)) = 0.9680$ ,  $\mu_2(TP(T)) = 0.9671$ ,  $TP_r^* = \text{Rs } 2145.3/\text{unit time}$

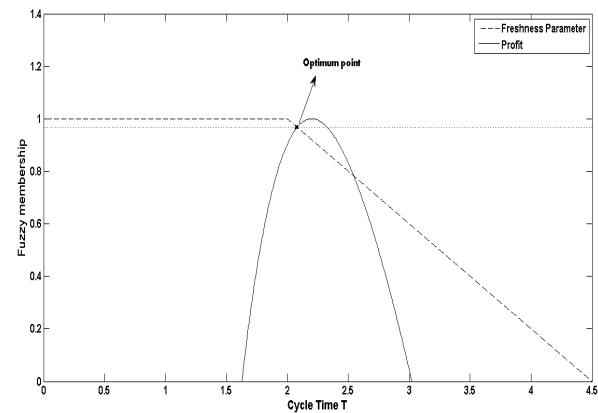


Fig. 1. Fuzzy membership vs. cycle time

**TABLE I: Sensitivity Analysis :  $TP_{tol}$  is varying**

SI NO	$TP_{tol}$	$T^*$	Maximum $\mu_1$ (FP(T))	Maximum $\mu_2$ (TP(T))	$TP_{Pr}^*$
1	100	2.115	0.9540	0.9516	2150.3
2	200	2.095	0.9620	0.9626	2147.7
3	300	2.080	0.9680	0.9671	2145.3
4	400	2.070	0.9720	0.9708	2143.5
5	500	2.060	0.9760	0.9728	2141.5

**TABLE II: Sensitivity Analysis :  $T_2$  is varying**

SI NO	$T_2$	$T^*$	Maximum $\mu_1$ (FP(T))	Maximum $\mu_2$ (TP(T))	$TP_{Pr}^*$
1	3.5	2.0650	0.9567	0.9579	2142.5
2	4	2.0750	0.9625	0.9641	2144.4
3	4.5	2.0800	0.9680	0.9671	2145.3
4	5.0	2.0850	0.9717	0.9699	2146.1
5	5.5	2.0900	0.9743	0.9725	2146.9

Next a sensitivity analysis is carried out by changing the tolerance limit of the total profit and observing the corresponding changes in the optimum values. The results are depicted in Table I . As  $TP_{tol}$  increases the values of membership functions of both the objectives functions increase at the expense of decrease in the optimum total profit. One more sensitivity analysis is also shown by changing the upper limit of freshness parameter , $T_2$  . The results are depicted in Table II. As  $T_2$  increases the values of membership functions of both the objectives functions as well as the optimum total profit increase.

#### 4. CONCLUSION

The optimum selling price, cycle time of the retailer, which results in maximum profit, is found. In this case the optimum combination is found to be  $S^*=177.1000$ ,  $T^*=2.2005$ ,  $TP_{max}=2155.1$ . However by compromising a little profit of Rs 9.8 /unit time we can maintain more fresh products thus satisfying the customers more. Also by changing tolerance limits of total profit and freshness parameter we can have different sets of optimum values.

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# Solving Fuzzy Transportation Problem with Triangular Fuzzy Number Using Grey Number

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**Abstract:** A fuzzy transportation problem comprises the transportation cost, supply and demand quantities in to fuzzy quantities. The aim of Fuzzy transportation is to discover the least transportation cost of some commodities through a capacitated network when the supply, demand and objectives are represented as fuzzy numbers. By converting fuzzy numbers into grey numbers, work aim is to solve fuzzy transportation problem which involves imprecise available supply, demand and unit cost coefficient with triangular possibility distributions by using linear and exponential membership functions. Furthermore, in this paper, fuzzy verdict classified with  $\alpha$ -level set for the decision maker. The developed algorithm aims to minimize cost with accessible supply constraint at each source and demand constraint at each destination. An example is given to demonstrate the performance of this developed algorithm.

**Keywords:** Transportation problem,  $\alpha$ -level set, Fuzzy membership function, Triangular fuzzy number

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## 1. INTRODUCTION

In conventional transportation problems it is assumed that decision maker is sure about the precise values of transportation cost, availability and demand of the product. In real world applications, all the parameters of the transportation problems may not be known precisely due to uncontrollable factors. This type of imprecise data is not always well represented by random variable selected from a probability distribution. Fuzzy number may represent this data. So, fuzzy decision making method is needed to solve fuzzy transportation problem (Samuel, 2009).

Zadeh was the first to introduce the concept of fuzzy set theory. For further discussions about fuzzy set theory, the reader may refer to Kaufmann. Zimmermann was the first to apply the concept of fuzzy set theory with suitable choices of membership functions, and to derive a fuzzy linear program identical to the maximin program. Dyson has claimed that Zimmermann's fuzzy linear programming model is an innovation in the field of multi-criterial decision making. Zimmermann applied fuzzy linear programming approaches to the linear vector maximum problem. It is shown by Zimmermann that solutions obtained using fuzzy linear programming are always efficient and that they also give an optimal compromise solution. Chanas et al. investigated transportation problems with fuzzy demands and supplies, and solved them using the parametric programming technique, in terms of the Bellman-Zadeh criterion. Stefan Chanas and Kuchta discussed transportation problems with fuzzy cost coefficients and transformed the problem into a bicriterial transportation problem with crisp objective function. Stefan Chanas and Dorota Kuchta also proposed an algorithm

which solves the transportation problem with fuzzy supply and demand values along with the integration condition imposed on the solution. Samir A. Abbas and Omar M. Saad proposed the concept of parametric study on transportation problems. Shiang-Tai Liu and Chiang Kao have discussed an idea based on Zadeh's extension principle, to transform the fuzzy transportation problem into a pair of mathematical programs. Nagoor Gani and Abdul Razak also presented fuzziness in preemptive goal programming formulation of a multi-objective unbalanced transportation problem with budgetary constraints in which the demand and budget are specified imprecisely (Samuel, 2009).

Oheigeartaigh proposed an algorithm for solving transportation problems where the capacities and requirements are fuzzy sets with linear or triangular membership functions. Saad and Abbas (Saad and Abbas 2003) discussed the solution algorithm for solving the transportation problem in fuzzy environment. Liu and Kao (Liu and Kao 2004) described a method for solving fuzzy transportation problems based on extension principle. Gani and Razak presented a two stage cost minimizing fuzzy transportation problem (FTP) in which supplies and demands are trapezoidal fuzzy numbers. A parametric approach is used to obtain a fuzzy solution and the aim is to minimize the sum of the transportation costs in the two stages. To deal with uncertainties of supply and demand parameters, Gupta and Mehlaawat transformed the past data pertaining to the amount of supply of the  $i$ th supply point and the amount of demand of the  $j$ th demand point using level  $(k, q)$  interval-valued fuzzy numbers. Dinagar and Palanivel investigated FTP, with the aid of trapezoidal fuzzy numbers. Fuzzy modified distribution method is

proposed to find the optimal solution in terms of fuzzy numbers. Pandian and Natarajan proposed a new algorithm namely, fuzzy zero point method for finding fuzzy optimal solution for such fuzzy transportation problems in which the transportation cost, supply and demand are represented by trapezoidal fuzzy numbers. Chen pointed out that in many cases it is not possible to restrict the membership function to the normal form and proposed the concept of generalized fuzzy numbers. In most of the papers the generalized fuzzy numbers are converted into normal fuzzy numbers through normalization process and then normal fuzzy numbers are used to solve the real life problems. Kaufmann and Gupta pointed out that there is a serious disadvantage of the normalization process. Amit Kumar and Amar Preet proposed a ranking function and generalised trapezoidal fuzzy numbers to solve fuzzy transportation problem (Amarpreet and Amit 2011). In this paper to solve the fuzzy transportation problem, first of all we convert fuzzy transportation problem into crisp transportation problem after that convert all data into grey numbers (Yao, Wang and Li 2009) to normalize the uncertainty and the remaining solution procedure is given below.

## 2. SOME PRELIMINARIES

### 2.1 Triangular Possibilistic Distribution (TPD)

Because of the imprecise nature of the uncertain parameters, the triangular possibilistic distribution (TPD) is commonly used due to its simplicity and computational effectiveness in obtaining data. In realistic circumstances, a DM can construct the TPD by using  $(c_i^m), (c_i^o)$  and  $(c_i^p)$  most possible value (possibility degree = 1), the most optimistic value (possibility degree = 0) and the most pessimistic value (possibility degree = 0) respectively. Objective function cost is defined at three positions as  $(c_i^m, 1), (c_i^p, 0)$  and  $(c_i^o, 0)$  which are minimized by shifting the three positions of TPD to the left because vertical coordinates of the points are fixed by 0 or 1 (Jayesh and Anita 2016).

### 2.2 $\alpha$ -Level Sets

An  $\alpha$ -level set is the most fundamental theory to establish an association between traditional and fuzzy set theories, which was introduced by Zadeh. The  $\alpha$ -level replicates the assurance of the DM regarding his fuzzy verdict; it can also be termed as the confidence level. The smallest  $\alpha$ -value capitulate an interval verdict with a large spread, which point out a high level of pessimism and uncertainty. The largest  $\alpha$ -value capitulate a smaller but more optimistic judgment in which the upper and lower bounds have a greater degree of membership in the initial fuzzy sets (Jayesh and Anita 2016).

## 3. MATHEMATICAL MODEL OF FUZZY TRANSPORTATION PROBLEM

Consider fuzzy transportation problem (Samuel, 2009) with  $m$  fuzzy origins and  $n$  fuzzy destinations in which a decision maker is uncertain about the precise values of transportation cost, supply and demand, may be formulated as follows:

### Model 1

$$\text{Minimize } Z = \sum_{i=1}^m \sum_{j=1}^n \tilde{c}_{ij} x_{ij}$$

Subject to

$$\sum_{j=1}^n x_{ij} = \tilde{a}_i, \quad i = 1, 2, \dots, m \quad (i)$$

$$\sum_{i=1}^m x_{ij} = \tilde{b}_j, \quad j = 1, 2, \dots, n \quad (ii)$$

$$x_{ij} \text{ is a non-negative triangular fuzzy number.} \quad (iii)$$

Where

$\tilde{a}_i = [a_i^m, a_i^o, a_i^p]$  be the fuzzy supply of the product at  $i^{\text{th}}$  source.

$\tilde{b}_j = [b_j^m, b_j^o, b_j^p]$  be the fuzzy demand of the product at  $j^{\text{th}}$  destination.

$\tilde{c}_{ij} = [c_{ij}^m, c_{ij}^o, c_{ij}^p]$  be the fuzzy transportation cost for unit quantity of the product from  $i^{\text{th}}$  source to  $j^{\text{th}}$  destination.

$x_{ij}$  be the fuzzy quantity of the product that should be transported from  $i^{\text{th}}$  source to  $j^{\text{th}}$  destination to minimize the total fuzzy transportation cost.

If  $\sum_{i=1}^m \tilde{a}_i = \sum_{j=1}^n \tilde{b}_j$  then fuzzy transportation problem is said to be balanced fuzzy transportation problem otherwise it is called unbalanced fuzzy transportation problem.

### 3.1 FORMULATION OF CRISP TRANSPORTATION PROBLEM (CTP)

To convert the model 1 into CTP, use TPD strategy to treat the imprecise objectives. The cost objective function is described as

$$\min Z = \min(Z^o, Z^m, Z^p) = \min \left( \sum_{i=1}^m \sum_{j=1}^n c_{ij}^o x_{ij}, \sum_{i=1}^m \sum_{j=1}^n c_{ij}^m x_{ij}, \sum_{i=1}^m \sum_{j=1}^n c_{ij}^p x_{ij} \right) \quad (iv)$$

Where  $\tilde{c}_{ij} = [c_{ij}^m, c_{ij}^o, c_{ij}^p]$ , which can be considered as follows:

$$(\min z_{11}, \min z_{12}, \min z_{13}) = \left( \sum_{i=1}^m \sum_{j=1}^n c_{ij}^o x_{ij}, \sum_{i=1}^m \sum_{j=1}^n c_{ij}^m x_{ij}, \sum_{i=1}^m \sum_{j=1}^n c_{ij}^p x_{ij} \right) \quad (v)$$

Eq. (iv) and Eq. (v) is associated with optimistic scenario, the most likely scenario and the pessimistic scenario respectively.

Using the  $\alpha$ -level sets concepts ( $0 \leq \alpha \leq 1$ ) each  $c_{ij}$  can be stated as

$$(c_{ij})_{\alpha} = \left( (c_{ij})_{\alpha}^o, (c_{ij})_{\alpha}^m, (c_{ij})_{\alpha}^p \right)$$

Where

$$(c_{ij})_{\alpha}^o = c_{ij}^o + \alpha(c_{ij}^m - c_{ij}^o), \quad (c_{ij})_{\alpha}^p = c_{ij}^p - \alpha(c_{ij}^p - c_{ij}^m), \\ (c_{ij})_{\alpha}^m = c_{ij}^m.$$

Hence Eq. (iv) can be written as:

$$(\min z_{11}, \min z_{12}, \min z_{13}) = \left( \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^o x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^m x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^p x_{ij} \right) \quad (vi)$$

To determine the optimistic, most-likely, and pessimistic scenarios by using the  $\alpha$ -level set concept, the FTP is converted into a crisp TP also called as crisp transportation model which is defined as follows:

## Model 2

$$(\min z_{11}, \min z_{12}, \min z_{13}) = \left( \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^o x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^m x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^p x_{ij} \right)$$

With constraints (i) – (iii)

## 4. METHODOLOGY

The Steps given below discussed solution procedure to find the solution of fuzzy transportation problem.

**Step 1** Consider Model 1 which can be formulated using triangular possibilistic distribution.

**Step 2** Define the crisp multi objective transportation model according to confidence level  $\alpha$ .

$$(\min z_{11}, \min z_{12}, \min z_{13}) = \left( \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^o x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^m x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^p x_{ij} \right)$$

With constraints (i) – (iii)

**Step 3** Convert objective function's data into grey numbers (Yao, Wang and Li 2009) by using the formula which is given below.

$$(r_{ij})_{\alpha}^o = \min_i \min_j \left\{ (c_{ij})_{\alpha}^o \right\} / (c_{ij})_{\alpha}^o, \\ (r_{ij})_{\alpha}^m = \min_i \min_j \left\{ (c_{ij})_{\alpha}^m \right\} / (c_{ij})_{\alpha}^m, \\ (r_{ij})_{\alpha}^p = \min_i \min_j \left\{ (c_{ij})_{\alpha}^p \right\} / (c_{ij})_{\alpha}^p,$$

Thereafter normalize data by subtracting each data from 1.

**Step 4** From Step 3, find out the positive ideal solution (PIS) and negative ideal solution (NIS).

**Step 5** In terms of the aspiration levels of each company, the initial fuzzy model stated, as follows:

## When Linear Membership Function

$$\mu_k(x) = \begin{cases} 1 & \text{if } Z_k \leq Z_k^{NIS} \\ 1 - \frac{Z_k - Z_k^{NIS}}{Z_k^{PIS} - Z_k^{NIS}}, & \text{if } Z_k^{NIS} < Z_k < Z_k^{PIS} \\ 0 & \text{if } Z_k \geq Z_k^{PIS} \end{cases}$$

is considered then Model which can be obtain in step 2 converted in the form of model 3 as

Maximize  $\lambda$

$$\text{Subject to } Z_k + \lambda(Z_k^{PIS} - Z_k^{NIS}) \leq Z_k^{PIS}$$

With the given constraints (i) – (iii), the non-negativity conditions as well as  $\lambda \geq 0$ , where  $\lambda = \min \{ \mu_k(x) \}$  (Jayesh and Anita 2016).

## When Exponential Membership Function

$$\mu_k^e(x) = \begin{cases} 1 & \text{if } Z_k \leq Z_k^{NIS} \\ \frac{e^{-s\psi_k(x)} - e^{-s}}{1 - e^{-s}} & \text{if } Z_k^{NIS} < Z_k < Z_k^{PIS} \\ 0 & \text{if } Z_k \geq Z_k^{PIS} \end{cases}$$

$$\text{Where } \psi_k(x) = \frac{Z_k - Z_k^{NIS}}{Z_k^{PIS} - Z_k^{NIS}}, \quad k = 1, 2, 3, \dots, K.$$

(Where  $s$  is a non-zero parameter prescribed by decision maker and  $(0 \leq \mu_k(x) \leq 1)$ ) is considered then Models which can be obtain in step 2 converted in the form of model 4 as

Maximize  $\lambda$

$$\text{Subject to } e^{-s\psi_k(x)} - (1 - e^{-s})\lambda \geq e^{-s} \text{ for all } k$$

With the given constraints (i) – (iii) and non-negativity restriction and  $\lambda \geq 0$  (Jayesh and Anita 2016).

Step: Find the solution of model 3 and Model 4.

If the obtained solution is accepted by the decision maker, then it is considered as the ideal compromise solution and the solution process is stopped, else the above solution method repeated until a satisfactory solution is achieved.

## 5. DEVELOPED ALGORITHM

To solve Fuzzy Transportation Problem (FTP) developed algorithm is as follows:

**Step 1** Formulate the model 1 using triangular probabilistic distribution as

$$\text{Minimize } Z = \sum_{i=1}^m \sum_{j=1}^n \tilde{c}_{ij} x_{ij}$$

**Step 2** Obtain the crisp transportation model according to  $\alpha$ -level set concept as

$$(\min z_{11}, \min z_{12}, \min z_{13}) = \left( \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^o x_{ij}, \sum_{i=1}^m \sum_{j=1}^n (c_{ij})_{\alpha}^m x_{ij}, \right.$$

With constraints (i) – (iii)

**Step 3** Convert fuzzy numbers into grey number by using the formula given in section 4 and thereafter normalize data by subtracting each data from 1.

**Step 4** Establish the positive ideal solution (PIS) and negative ideal solution (NIS) for the objective functions.

**Step 5** Develop model 3 and model 4 and solve using LINGO package. The solutions obtained are compromise solutions.

Model 3 Maximize  $\lambda$

$$\text{Subject to } Z_k + \lambda (Z_k^{PIS} - Z_k^{NIS}) \leq Z_k^{PIS}$$

With the given constraints, non-negativity restriction and  $\lambda \geq 0$ .

Model 4 Maximize  $\lambda$

$$\text{Subject to } e^{-s\psi_k(x)} - (1 - e^{-s})\lambda \geq e^{-s} \text{ for all } k$$

With the given constraints and non-negativity restriction and  $\lambda \geq 0$ .

## 6. ILLUSTRATION

A company has four sources  $S_1, S_2, S_3$  and  $S_4$  and four destinations  $D_1, D_2, D_3$  and  $D_4$ . The fuzzy transportation cost for unit quantity of the product from  $i^{\text{th}}$  source to  $j^{\text{th}}$  destination is  $C_{ij}$  where

$$[c_{ij}]_{4 \times 4} = \begin{bmatrix} (5,10,15) & (5,10,20) & (5,15,20) & (5,10,15) \\ (5,10,20) & (5,15,20) & (5,10,15) & (10,15,20) \\ (5,10,20) & (10,15,20) & (10,15,20) & (5,10,15) \\ (10,15,25) & (5,10,15) & (10,20,30) & (10,15,25) \end{bmatrix}$$

And fuzzy supply of the product at sources are  $((10,15,20), (5,10,15), (20,30,40), (15,20,25))$  and the fuzzy demand of the product at destinations are  $((25,30,35), (10,15,20), (5,15,20), (10,15,25))$

respectively (Shugani, Abbas and Gupta 2012).

**Solution:** **Step 1** Fuzzy transportation problem is as follows:

	$D_1$	$D_2$	$D_3$	$D_4$	Supply
$S_1$	(5, 10, 15)	(5, 10, 20)	(5, 15, 20)	(5, 10, 15)	(10, 15, 20)
$S_2$	(5, 10, 20)	(5, 15, 20)	(5, 10, 15)	(10, 15, 20)	(5, 10, 15)
$S_3$	(5, 10, 20)	(10, 15, 20)	(10, 15, 20)	(5, 10, 15)	(20, 30, 40)
$S_4$	(10, 15, 25)	(5, 10, 15)	(10, 20, 30)	(10, 15, 25)	(15, 20, 25)
Demand	(25, 30, 35)	(10, 15, 20)	(5, 15, 20)	(10, 15, 25)	

**Step 2** The crisp transportation problem according to  $\alpha$ -level as  $\alpha = 0.1, \alpha = 0.5$  and  $\alpha = 0.9$ .

$$\text{For } \alpha = 0.1, (c_{ij})_{0.1} = \begin{bmatrix} (5.5,10,14.5) & (5.5,10,19) & (6,15,19.5) & (5.5,10,14.5) \\ (5.5,10,19) & (6,15,19.5) & (6,15,19.5) & (10.5,15,19.5) \\ (5.5,10,19) & (10.5,15,19.5) & (10.5,15,19.5) & (5.5,10,14.5) \\ (10.5,15,24) & (5.5,10,14.5) & (11,20,29) & (10.5,15,24) \end{bmatrix}$$

$$\text{For } \alpha = 0.5, (c_{ij})_{0.5} = \begin{bmatrix} (7.5,10,12.5) & (7.5,10,15) & (10,15,17.5) & (7.5,10,12.5) \\ (7.5,10,15) & (10,15,17.5) & (10,15,17.5) & (12.5,15,17.5) \\ (7.5,10,15) & (12.5,15,17.5) & (12.5,15,17.5) & (7.5,10,12.5) \\ (12.5,15,20) & (7.5,10,12.5) & (15,20,25) & (12.5,15,20) \end{bmatrix}$$

$$\text{For } \alpha = 0.9, (c_{ij})_{0.9} = \begin{bmatrix} (9.5, 10, 10.5) & (9.5, 10, 11) & (14, 15, 15.5) & (9.5, 10, 10.5) \\ (9.5, 10, 11) & (14, 15, 15.5) & (14, 15, 15.5) & (14.5, 15, 15.5) \\ (9.5, 10, 11) & (14.5, 15, 15.5) & (14.5, 15, 15.5) & (9.5, 10, 10.5) \\ (14.5, 15, 16) & (9.5, 10, 10.5) & (19, 20, 21) & (14.5, 15, 16) \end{bmatrix}$$

**Step 3** Convert data which can be obtain in step 2 into grey numbers by using the above formula and subtract each data from 1 we obtain the following matrices.

For  $\alpha = 0.1$

$$(r_{ij})_{0.1} = \begin{bmatrix} 0 & (0, 0, 0.2368) & (0.0833, 0.3333, 0.2564) & 0 \\ (0, 0, 0.2368) & (0.0833, 0.3333, 0.2564) & (0.0833, 0.3333, 0.0256) & (0.4762, 0.3333, 0.2564) \\ (0, 0, 0.2368) & (0.4762, 0.3333, 0.2564) & (0.4762, 0.3333, 0.2564) & 0 \\ (0.4762, 0.3333, 0.3958) & 0 & (0.5, 0.5, 0.5) & (0.4762, 0.3333, 0.3958) \end{bmatrix}$$

For  $\alpha = 0.5$

$$(r_{ij})_{0.5} = \begin{bmatrix} 0 & (0, 0, 0.1667) & (0.25, 0.3333, 0.2857) & 0 \\ (0, 0, 0.1667) & (0.25, 0.3333, 0.2857) & (0.25, 0.3333, 0.1429) & (0.4, 0.3333, 0.2857) \\ (0, 0, 0.1667) & (0.4, 0.3333, 0.2857) & (0.4, 0.3333, 0.2857) & 0 \\ (0.4, 0.3333, 0.375) & 0 & (0.5, 0.5, 0.5) & (0.4, 0.3333, 0.375) \end{bmatrix}$$

For  $\alpha = 0.9$

$$(r_{ij})_{0.9} = \begin{bmatrix} 0 & (0, 0, 0.0455) & (0.3214, 0.3333, 0.3226) & 0 \\ (0, 0, 0.0455) & (0.3214, 0.3333, 0.3226) & (0.3214, 0.3333, 0.2903) & (0.3448, 0.3333, 0.3226) \\ (0, 0, 0.0455) & (0.3448, 0.3333, 0.3226) & (0.3448, 0.3333, 0.3226) & 0 \\ (0.3448, 0.3333, 0.3438) & 0 & (0.5, 0.5, 0.5) & (0.3448, 0.3333, 0.3438) \end{bmatrix}$$

**Step 4** Establish the positive ideal solution (PIS) and negative ideal solution (NIS) for the objective function.

**TABLE 2: PIS and NIS for objective function**

$\alpha$ - level	Solutions	Objective		
		$Z_1$	$Z_2$	$Z_3$
$\alpha = 0.1$	PIS	3.2291	5.4166	5.5655
	NIS	27.9762	19.5831	22.5708
$\alpha = 0.5$	PIS	4.6875	5.4166	6.0417
	NIS	23.5	19.5831	21.1309
$\alpha = 0.9$	PIS	5.3125	5.4166	5.7221
	NIS	20.2588	19.5831	20.0567

**Step 5** Solutions obtained in Table 3 and Table 5 from Model 4 and Model 5 respectively are compromise solutions given below.

#### Linear Membership Function

**TABLE 3: Results for  $\alpha = 0.1, \alpha = 0.5$  and  $\alpha = 0.9$**

$\alpha$ - level	$\lambda$	$Z_1$	$Z_2$	$Z_3$	Optimal allocations
$\alpha = 0.1$	0.98251	445.4	843.	1264.	$x_{11}, x_{23}, x_{31}, x_{33}, x_{34}, x_{41}, x_{42}, x_{43}$
	79	36	75	56	
$\alpha = 0.5$	0.99248	621.8	843.	1079.	$x_{11}, x_{21}, x_{23}, x_3, x_{34}, x_{41}, x_{42}, x_{43}$
	66	75	75	65	
$\alpha = 0.9$	0.99999	799.3	843.	891.2	$x_{11}, x_{21}, x_{23}, x_3, x_{34}, x_{42}, x_{43}$
	65	75	75	5	



## Exponential Membership Function

**TABLE 4: Different values of shape parameters**

Case	Shape parameter $(s_1, s_2, s_3)$
Case – 1	(0.1, 0.3, 0.5)
Case – 2	(0.3, 0.5, 0.1)
Case – 3	(0.5, 0.1, 0.3)
Case – 4	(1, 0.7, 1.5)
Case – 5	(1.7, 1.1, 2)

**TABLE 5: Results for  $\alpha = 0.1, \alpha = 0.5$  and  $\alpha = 0.9$**

$\alpha$ - level	Case	$\lambda$	$Z_1$	$Z_2$	$Z_3$	Optimal allocations
$\alpha = 0.1$	1	0.97849 45	445.8 77	843.7 5	1264. 12	$x_{11}, x_{23}, x_{31}, x_{33}$ $x_{34}, x_{41}, x_{42}, x_{43}$
	2	0.98066 59	444.5 92	843.7 5	1265. 41	
	3	0.98039 75	445.8 92	843.7 5	1264. 11	
	4	0.97004 78	447.0 52	843.7 5	1262. 95	
	5	0.96439 86	447.1 09	843.7 5	1262. 89	
$\alpha = 0.5$	1	0.99087 60	621.8 75	843.7 5	1079. 57	$x_{11}, x_{21}, x_{23}, x_{31}$ $x_{34}, x_{41}, x_{42}, x_{43}$
	2	0.99143 79	621.8 75	843.7 5	1079. 82	
	3	0.99169 62	616.9 55	843.7 5	1071. 37	
	4	0.98772 71	621.8 75	843.7 5	1079. 37	
	5	0.98540 28	621.8 75	843.7 5	1079. 36	
$\alpha = 0.9$	1	1	799.3 75	843.7 5	891.2 5	$x_{11}, x_{21}, x_{23}, x_{31}$ $x_{34}, x_{42}, x_{43}$
	2	1	799.3 75	843.7 5	891.2 5	
	3	0.99999 86	799.3 75	843.7 5	891.2 5	
	4	1	799.3 75	843.7 5	891.2 5	
	5	1	799.3 75	843.7 5	891.2 5	

Different cases of shape parameter ‘s’ gives the solution sets at different confidence level  $\alpha = 0.1$ ,  $\alpha = 0.5$  and  $\alpha = 0.9$ . Moreover, it has been observed that as the values of confidence level  $\alpha$  increases, the values of the aspiration level  $\lambda$  increases. The solution sets obtained by linear and exponential membership functions are given in Table 3 and Table 5. The real life uncertainties are taken as in terms of fuzzy numbers, the present work may be helpful in practical circumstances.

## 7. CONCLUSION

This paper proposed a new method to solve fuzzy transportation problem with triangular fuzzy numbers and obtained compromise solutions using linear and exponential membership functions. Minimize uncertainty is the advantage of grey numbers, so in this paper grey numbers applied for the solutions of the fuzzy transportation problem. The present work may be helpful in controlling similar real life transportation problems in big industries involving varied numerous confliction objectives.

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# Demonstration and Implementation of Heat Treatment Search Algorithm for Standard Benchmark Functions

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**Abstract:** Industries always try to minimize wastage of material, money, time and other resources to maximize their profit. For these purposes, optimization techniques are often used in industrial planning, design and control for solving problems related to plant layout, stock control, routing, scheduling, financial etc. Various algorithms are available for solving these type of problems having their individual advantages and disadvantages. In this article heat transfer search algorithm is described which is based on the law of thermodynamics and heat transfer approach. Performance of this algorithm is investigated by implementing it for standard benchmark functions namely Rastrigin function, Booth's function and Rosenbrock function. Results of these functions validate performance of the proposed algorithm. Step by step calculations for Rastrigin function is also presented for easy understanding of this algorithm.

**Keywords:** Optimization techniques; Heat transfer search algorithm; Rastrigin function; Booth's function; Rosenbrock function

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## 1. INTRODUCTION

Optimal state is one of the most fundamental principles in the world for example atoms always forms bonds to minimize energy of their electron, thermal systems always try to minimize their energy, people want maximum happiness with minimum amount of effort. Similarly in industries, sales and profit should be maximum with low costs. Therefore, optimization is necessary and oldest science which is also used in today's life (Weise, 2008).

Optimization algorithm is defined as algorithm to finding solutions of real function which provide maximum or minimum value of function and satisfy all the conditions. There may be number of solutions that satisfy all the conditions and provide maximum or minimum value of function. These are called acceptable solutions and solution best among them is known as optimum solution (Togan, 2012).

Optimization provide best possible solution  $X^*$  for the set of criteria  $F$  from given set  $X$ . These criteria are called objective functions and express as a mathematical functions. Optimization techniques supports decision-making across a wide range of industrial problems which may be large or small, straightforward or complicated. Manufacturing, transportation, health care, advertising, telecommunication, financial services, energy and utilities, marketing and sales and many more industries use optimization algorithm for solving problems related to long time planning, scheduling and similar types of problems.

Optimization of large scale problems have many difficulties such as dimensionality, multimodality and differentiability. Conventional techniques are not able to solve such large

scale optimization problems. Also these techniques are not able to solve problems which have many local minimum and maximum points. For solving such types of large scale problem meta-heuristic optimization techniques gives better result (Rao et al., 2012).

In this article, various meta-heuristic optimization techniques are presented in section 2. Details of heat transfer search (HTS) algorithm is covered in section 3. Whereas section 4 presents the sample calculation for Rastrigin function. Section 5 covered validation of HTS algorithm and in section 6 conclusion of the work is presented.

## 2. VARIOUS OPTIMIZATION ALGORITHM

Metaheuristics algorithms are based on the law of nature and science and few important algorithms are listed as follow: Genetic Algorithm (GA) which works on the Darwinian's evolutionary theory (Holland, 1975), artificial immune algorithm (AIA) which works on principles and mechanisms of the immune system of living beings (De Castro and Von Zuben, 2002), Differential Evolution (DE) (Storn and Prince, 1997) algorithm is similar to GA, bacteria foraging optimization (BFO) which works on social foraging behaviour of *Escherichia coli* (Passino, 2002), ant colony optimization (ACO) which works on behaviour of the ant for the food (Dorigo and Stutzle, 2004), artificial bee colony (ABC) which works on the information sharing ability of honey bee swarm (Karaboga, 2005), particle swarm optimization (PSO) which works on the intelligent behaviour of migrating birds (Kennedy and Eberhart, 1995), biogeography based optimization (BBO) which works on a principle of immigration and emigration of the species from one place to the other (Simon, 2008), teaching

learning based optimization (TLBO) which works on the effect of influence of a teacher on learners (Rao et al., 2011), gravitational search algorithm (GSA) which works on law of gravity and mass interaction (Rashedi et al., 2009) and heat transfer search (HTS) algorithm which works on law of thermodynamics and heat transfer approach (Patel and Savsani, 2015). HTS algorithm is recently developed algorithm which claims to be more superior than other algorithm (Patel and Savsani, 2015). Hence, in this article, this algorithm is considered and in next section its detailed working is presented following by result discussion based on standard benchmark functions.

### 3. HEAT TRANSFER SEARCH (HTS) ALGORITHM

Patel and Savsani (2015) proposed the HTS algorithm which is based on the law of thermodynamics and heat transfer, which states that if there is imbalance between system and surrounding or within the system, then system always try to attain equilibrium state with surrounding by transferring heat through conduction, convection or radiation. In HTS algorithm, some solutions are randomly generated which is known as initial population and is analogous to the clusters of molecules responsible for heat transfer and different design variables are analogous to different temperature levels. Objective function value is considered as energy level of molecules. From the chosen population, best solution is considered as the surrounding and remaining solutions represent a system. The search process of HTS algorithm was done through conduction phase, convection phase or radiation phase. These phases have equal probability and one of the phase is decided by randomly generated number. Conduction factor, convection factor or radiation factor is introduced into phases for controlling the trade off between exploration and exploitation ((Patel and Savsani, 2015).

For HTS algorithm, first initial population of  $n$  solutions are generated. Each solution has  $m$  design variables which also known as dimensional vector. After initial generation, these solutions are updated in each generation  $g$  ( $g=1, 2, \dots, G_{max}$ ) by conduction, convection or radiation. These three phases are explained below (Patel and Savsani, 2015).

#### 3.1 Conduction Phase

In conduction phase, heat is transferred from higher energetic molecules to lower energetic molecules. For conduction heat transfer, direct physical contact between system and surrounding is necessary and governed by the Fourier's equation. During conduction phase solutions are updated by Eq. (i) and (ii)

$$X_{j,i}^{new} = X_{k,i}^{old} + CDS_1 \text{ If } f(X_j) > f(X_k) \quad (i)$$

$$X_{j,i}^{new} = X_{j,i}^{old} + CDS_2 \text{ If } f(X_k) > f(X_j) \quad (ii)$$

Where,  $j$  is a solution number and  $j \in [1, n]$ ,  $i$  is a design variable and  $i \in [1, m]$  and  $k$  is a randomly selected solution from the population.

If  $g \leq G_{max} / CDF$ , the solutions are updated by Eq. (iii) and (iv)

$$CDS_1 = -R^2 X_{k,i}^{old} \quad (iii)$$

$$CDS_2 = -R^2 X_{j,i}^{old} \quad (iv)$$

If  $g \geq G_{max} / CDF$ , the solutions are updated Eq. (v) and (vi)

$$CDS_1 = -r_i X_{k,i}^{old} \quad (v)$$

$$CDS_2 = -r_i X_{j,i}^{old} \quad (vi)$$

Where,  $r_i$  is randomly generated value between 0 and 1. In this phase only one design variable is updated. Exploration and exploitation tendency of the conduction phase are decided by conduction factor (CDF) and Patel and Savsani (2015) suggested appropriate value of conduction factor as 2 by conducting so many trials.

#### 3.2 Convection Phase

In convection phase, heat transfer takes place due to fluid motion and governed by Newton's law. Eq. (vii) is used for convection phase

$$X_{j,i}^{new} = X_{j,i}^{old} + COS \quad (vii)$$

$$COS = R(X_s - X_{ms} * TCF) \quad (viii)$$

Where,  $X_s$  is temperature of the surrounding and taken as lowest value from previous solution;  $X_{ms}$  is the mean temperature of the system; COS is convection step. Due to heat transfer, temperature of the system was changed. The surrounding was considered as a heat sink, hence temperature of it remain constant. For considering this effect, temperature change factor (TCF) was introduced by Patel and Savsani (2015) in HTS algorithm and given by Eq. (ix) and (x)

$$TCF = abs(R - r_i) \text{ If } g \leq G_{max} / COF \quad (ix)$$

$$TCF = round(1 + r_i) \text{ If } g \geq G_{max} / COF \quad (x)$$

Where, COF is convection factor as its value set as 10 (Patel and Savsani, 2015).

#### 3.3 Radiation Phase

In radiation phase heat transfer takes place due to electromagnetic wave between system and surrounding and does not require any medium. It is described by the Stefan-Boltzmann law and solutions are updated by Eq. (xi)

$$X_{j,i}^{new} = X_{j,i}^{old} + RDS \quad (xi)$$

If  $g \leq G_{max}$  / CDF, RDS is given by following Eq. (xii) and (xiii)

$$RDS = R(X_{k,i}^{old} - X_{j,i}^{old}) \text{ If } f(X_j) > f(X_k) \quad (xii)$$

$$RDS = R(X_{j,i}^{old} - X_{k,i}^{old}) \text{ If } f(X_k) > f(X_j) \quad (xiii)$$

If  $g \geq G_{max}$  / CDF, RDS is given by following Eq. (xiv) and (xv)

$$RDS = r_i(X_{k,i}^{old} - X_{j,i}^{old}) \text{ If } f(X_j) > f(X_k) \quad (iv)$$

$$RDS = r_i(X_{j,i}^{old} - X_{k,i}^{old}) \text{ If } f(X_k) > f(X_j) \quad (v)$$

Where,  $R$  is the probability number of phase and RDS(Radiation factor) is use to balance the exploration and exploitation and set as 2 (Patel and Savsani, 2015)

After updating population, greedy selection was done between updated solution and previous solution. After this, worst solutions of population were replaced by elite solution of previous generation. If duplicate solutions are found in the population after replacement of worst solutions, one of duplicate solution is modified by Eq. (xvi) and (xvii) (Degertekin et al., 2017).

$$x_j^{new} = x_j^{old} + r_j x_j^{old} \quad \text{if } 0.0 < r_j < 0.5 \quad (vi)$$

$$x_j^{new} = x_j^{old} - (1 - r_j) x_j^{old} \quad \text{if } 0.5 < r_j < 1.0 \quad (vii)$$

Above processes are continues until the maximum generation ( $G_{max}$ ) is reached. In this article, above mentioned approach is now used to solve various standard benchmark functions. Various standard benchmark functions or test functions, which are artificial problems are used to verify efficiency, reliability and validity of optimization algorithm (Dieterich and Hartke, 2012). In this article, three different standard benchmark functions are considered namely Rastrigin function, Booth's function and Rosenbrock function. In section 4, step by step calculations

of Rastrigin function is presented for easy understanding, using HTS algorithm and section 5 summarises the results of all these functions.

#### 4. SAMPLE CALCULATION FOR RASTRIGIN FUNCTION

Rastrigin's function has less local minimum within the search space  $[-5.12, 5.12]$  though its overall shape is flatter that creates difficulty to convergence towards the global optimum at  $x_i=0$  (Dieterich and Hartke, 2012). This function can be solved easily by using proposed algorithm. Step by step calculations are discussed in following subsections.

##### Step 1-Define objective function and parameters:

Objective function:  $f(x) = An + (x^2 - A \cos(2\pi x)) + (y^2 - A \cos(2\pi y))$  Where,  $A=10$ ;  $n=2$ .

$$S/T \quad 0 \leq x, y \leq 10$$

Following parameters are considered for above objective function

Population size = 10, Number of design variables = 2, Elite design set size= 2

**Step 2-Evaluation of initial populations:** During this step, some solutions are generated randomly as shown in table I. From these solutions, best two solutions that satisfy all criteria are selected as elite solution for further uses. Solutions 1 and 7 have minimum value of function hence these are selected as elite solution.

**Step 3- First generation:** In this step a random number is generated and according to value of this number, appropriate phase is selected for updating the initial population. Consider value of random number is 0.123 which is corresponding to conduction phase, hence initial population is updated by Eq.(i) and (ii). In these eq, solution 2 is selected as random solution.

TABLE I: Step-2				TABLE II: Step-3				TABLE III: Step-4			
No	X1	X2	f(X)	No	X1	X2	f(X)	No	X1	X2	f(X)
1	4.1452	1.7567	33.7307	1	4.1452	2.0579	25.9533	1	4.1452	2.0579	25.9533
2	4.6484	2.0895	43.4712	2	4.6484	1.0244	38.7330	2	4.6484	1.0244	38.7330
3	7.6396	9.0515	157.2080	3	7.6396	2.0579	79.6463	3	7.6396	2.0579	79.6463
4	8.1820	6.7539	128.1739	4	8.1820	2.0579	77.6926	4	8.1820	2.0579	77.6926
5	1.0022	4.6847	36.9415	5	1.0022	2.0579	5.8936	5	1.0022	2.0579	5.8936
6	1.7812	9.1213	97.1927	6	1.7812	2.0579	16.1149	6	1.7812	2.0579	16.1149
7	3.5963	1.0401	32.5544	7	3.5963	2.0579	36.0448	7	3.5963	1.0401	32.5544
8	0.5670	7.4555	94.6421	8	0.5670	2.0579	24.3355	8	0.5670	2.0579	24.3355
9	5.2189	7.3627	106.0039	9	5.2189	2.0579	40.1804	9	5.2189	2.0579	40.1804
10	3.3585	5.6186	76.4981	10	3.3585	2.0579	32.4685	10	3.3585	2.0579	32.4685

**Step 4- Greedy selection:** In this step best solution is selected from updated and previous solution.

Table IV: Step-5				Table V: Step-6				Table VI: Step-7			
No	X1	X2	f(X)	No	X1	X2	f(X)	No	X1	X2	f(X)
1	4.1452	2.0579	25.9533	1	4.1452	2.0579	25.9533	1	4.2188	2.2742	42.5420
2	4.6484	1.0244	38.7330	2	4.6484	1.0244	38.7330	2	4.5073	1.0277	41.5128
3	3.5963	1.0401	32.5544	3	3.5963	1.0401	32.5544	3	3.5963	1.0401	32.5544
4	4.1452	1.7567	33.7307	4	4.1452	1.7567	33.7307	4	4.0716	1.6043	38.0738
5	1.0022	2.0579	5.8936	5	1.0022	2.0579	5.8936	5	0.6543	2.2742	32.7747
6	1.7812	2.0579	16.1149	6	1.7812	2.0579	16.1149	6	1.5377	2.2742	38.7737
7	3.5963	1.0401	32.5544	7	2.1478	0.6212	26.2479	7	1.9535	0.5321	24.3204
8	0.5670	2.0579	24.3355	8	0.5670	2.0579	24.3355	8	0.1607	2.2742	21.3959
9	5.2189	2.0579	40.1804	9	5.2189	2.0579	40.1804	9	5.0012	1.8415	32.9671
10	3.3585	2.0579	32.4685	10	3.3585	2.0579	32.4685	10	3.3266	2.2742	42.3833

**Step 5:**After greedy selection, worst solutions of an above step is replaced by elite solutions of previous generation. Solutions 3 and 4 have maximum values hence these are replaced by elite solution of initial populations. These solutions do not have repetition hence replacement of these is not required. Again two best solutions are selected from this as elite solution for the next generation.

**Step 6- Modification of duplicate solutions of above step:**Duplicate solutions are replaced by Eq. (xvi) and (xvii)

**Step 7-Second generation:** Consider value of R for second generation as 0.563 which is corresponding to radiation phase hence above solutions are updated by Eq. (xi)

**Step 8-Greedy selection for second generation:**

Table VII: Step-8				Table VIII: Step-9				Table IX: Step-10			
No.	X1	X2	f(X)	No.	X1	X2	f(X)	No	X1	X2	f(X)
1	4.1452	2.0579	25.9533	1	4.1452	2.0579	25.9533	1	2.9798	2.4797	35.0277
2	4.6484	1.0244	38.7330	2	1.0022	2.0579	5.8936	2	-0.1632	2.4797	30.9067
3	3.5963	1.0401	32.5544	3	3.5963	1.0401	32.5544	3	2.4309	1.4620	46.8366
4	4.1452	1.7567	33.7307	4	1.7812	2.0579	16.1149	4	0.6158	2.4797	43.9165
5	1.0022	2.0579	5.8936	5	1.0022	2.0579	5.8936	5	-0.2685	2.2635	27.2039
6	1.7812	2.0579	16.1149	6	1.7812	2.0579	16.1149	6	0.7430	2.6268	34.8813
7	1.9535	0.5321	24.3204	7	1.9535	0.5321	24.3204	7	0.7881	0.9540	9.5758
8	0.1607	2.2742	21.3959	8	0.1607	2.2742	21.3959	8	-1.0047	2.6961	21.6044
9	5.0012	1.8415	32.9671	9	5.0012	1.8415	32.9671	9	3.8358	2.2634	35.5394
10	3.3585	2.0579	32.4685	10	3.3585	2.0579	32.4685	10	2.1931	2.4797	37.3775

**Step 9:** Replacement of the worst solutions of above step by elite solution of second generation. These solutions do not contain any duplicate solution hence third generation is carried out.

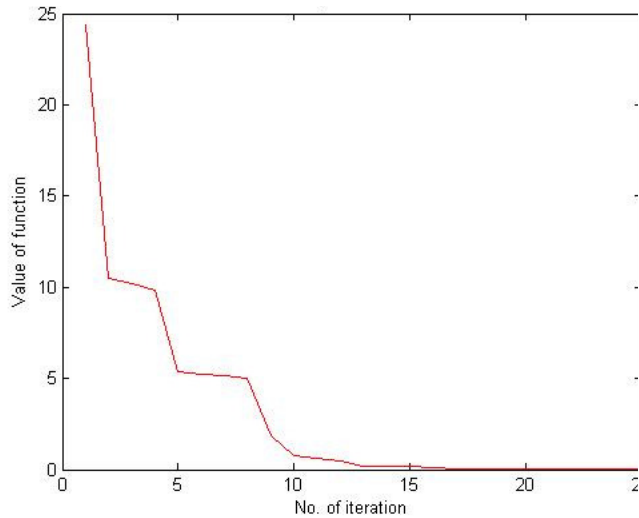
**Step 10- Third generation:** Consider value of R for the third generation is 0.852 which is corresponding to convection phase hence above solutions are updated by Eq. (vii) and (viii)

**Step 11- Greedy selection for the third generation**

**Step 12- Replacement of the worst solutions of above step by elite solution of the second generation**

Table X: Step-11				Table XI: Step-12			
No..	X1	X2	f(X)	No.	X1	X2	f(X)
1	4.1452	2.0579	25.9533	1	4.1452	2.0579	25.9533
2	1.0022	2.0579	5.8936	2	1.0022	2.0579	5.8936
3	3.5963	1.0401	32.5544	3	0.8969	1.8417	10.7751
4	1.7812	2.0579	16.1149	4	1.7812	2.0579	16.1149
5	0.8969	1.8417	10.7751	5	0.8969	1.8417	10.7751
6	1.9084	2.2049	17.3171	6	1.9084	2.2049	17.3171
7	0.7881	0.9540	9.5758	7	0.7881	0.9540	9.5758
8	0.1607	2.2742	21.3959	8	0.1607	2.2742	21.3959
9	5.0012	1.8415	32.9671	9	1.0022	2.0579	5.8936
10	3.3585	2.0579	32.4685	10	3.3585	2.0579	32.4685

After third generation, minimum solution obtain is 5.8936 for X1=1.0022 and X2=2.0579. Above steps are executed until the maximum generation. Graph of number of iteration to value of function is shown in Fig 1 which shows that values of functions converges very easily towards global minimum by HTS algorithm.



**Fig. 1 Graph of value of function vs no. of iteration**

## 5. RESULTS OF ALL FUNCTIONS

To validate the performance of HTS algorithm, it is applied to standard benchmark functions namely Rastrigin function, Booth's function and Rosenbrock function. Results of these functions are obtained by MATLAB 2013 and summarised below.

**5.1 Booth's Function** (Jamil and Yang, 2013): Continuous, non-separable, differentiable, non-scalable.

$f(x) = (x + 2y - 7)^2 + (2x + y - 5)^2$ ; subjected to  $-10 \leq x \leq 10, x_2 \leq 10$ ;

solutions:  $x=1$  and  $y=3$ ; no of iterations: 23; elapsed time is 5.409509 seconds.

**5.2 Rosenbrock Function** (Rosenbrock, 1960): Continuous, scalable, differentiable, non-separable.

$f(x) = 100(y - x^2)^2 + (x - 1)^2$ ; subjected to  $-30 \leq x \leq 30, x_2 \leq 30$ ;

solutions:  $x=1$  and  $y=1$ ; no of iterations: 769; elapsed time is 5.021851seconds.

**5.3 RastriginFunction:**

$f(x) = An + (x^2 - A \cos(2\pi x)) + (y^2 - A \cos(2\pi y))$ , where,  $A=10, n=2$ ; subjected to  $0 \leq x \leq 10, x_2 \leq 10$ ; solutions:  $x=0$  and  $y=0$ ; no of iterations: 25.0; elapsed time is 2.506285 seconds.

## 6. CONCLUSIONS

In this article, a metaheuristic algorithm known as Heat transfer search algorithm have been discussed

HTS algorithm keeps balance between exploration and exploitation during search process by implementing conduction factor, convection factor and radiation factor and provides global optimum solution for various types of industrial problem. Validity of this algorithm is checked by implementing this algorithm for three standard benchmark functions. Results from these validations indicate that the proposed algorithm is better or as par with the existing algorithms for solving optimization problems. This has a good convergence capability. This algorithm also uses for constraint problems by considering penalty and for multi objective functions with minormodification.

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# Fuzzy TOPSIS for Initial Idea Screening in Bus Body Building Industry

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**Abstract:** Now a day because of stiffer global competition, New Product Development (NPD) has become one of the core functions of the Corporate. At the earlier stages of product development, there are numerous new product ideas. The project screening phase is used to eliminate ideas having high probability of failure. The decision making may involve quantitative as well as qualitative data. Imprecise judgement can also come in to picture because of multidisciplinary NPD team members involved in the decision making process. The challenge lies in evaluating and selecting the best idea. Hence, the new product development is basically a Multi Attribute Decision Making (MADM) problem which can be tackled by using methods like Fuzzy TOPSIS. This paper deals with initial idea screening of a new product in case of a bus body building industry using Fuzzy TOPSIS approach. The approach in this paper consists of three steps. In step 1, the new product ideas and criteria's are identified. In step 2, decision makers provide the linguistic ratings for criteria weightages as well as linguistic ratings for alternatives against each criterion. In step 3, fuzzy TOPSIS is applied to select the best new product idea.

**Keywords:** NPD, MADM, Fuzzy TOPSIS, Idea Screening.

## 1. INTRODUCTION

New product development plays a vital role in global market because of stiff completion and customer satisfaction. Development of new product satisfying quality, performance and cost is the necessity of the hour. This becomes more important for companies having shorter product life cycle. In most cases, the data available might be limited, uncertain or not reliable. This creates difficulties in conducting assessment at early design stage. Uncertainty may arise from sources which are internal as well as external including technical, management and commercial issues. A structured approach is required to be used that can facilitate practitioners and decision-makers to evaluate the relative importance among various elements and factors that affect NPD decisions. Hence, the New Product Development (NPD) is basically a multi attribute decision making problem. There are several methods which can be applied to tackle MCDM problems. Fuzzy TOPSIS is one of the methods that is commonly used and works satisfactorily in various applications (Aloini et al., 2014; Awasthi et al. 2011; Dymova et al., 2013; Rouyendegh et al., 2014; Wang and Lee 2007).

## 2. IDEA SCREENING PHASE OF NPD

Early stage of new product development involves many new product ideas. All of these ideas might not be feasible to implement and also there are chances that some of these ideas may have high probability of failure. The project screening phase helps in carrying out the elimination of bad ideas. Selecting the right product idea for development and

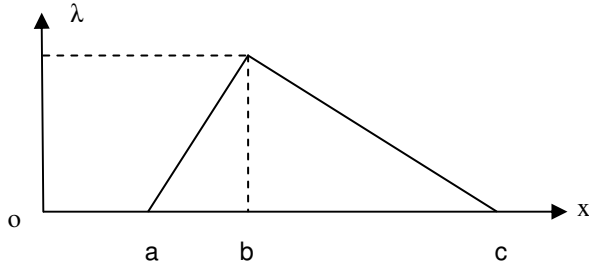
commercialization is the most important step for success of NPD (Chin et al., 2008). There are situation wherein data collected may be qualitative in nature or there might be uncertainty in the data. Imprecise Judgement can also come in to picture because of multidisciplinary NPD team members involved in the decision making process. The decision makers might have limited experience with respect to the new product ideas and their ability to judge which criteria is of more importance and also rating the criteria against each alternative is sometimes questionable. This type of complexity requires the use of multi criteria decision making techniques during the project screening stage (Wang & Chin, 2008; Lin, 2007, Geng 2010).

## 3. FUZZY TOPSIS METHOD

Zadeh (1965) introduced the fuzzy set theory which is an extension of the classical set theory. Triangular fuzzy number (TFN) is the most commonly used (Erturul, R. and Karakaolu, 2007; Lima Junior et al., 2014). The TFN is represented as follows:  $A = (a, b, c)$ . The parameter 'a' gives the smallest possible value, 'b' gives the peak value and 'c' gives the largest possible value of the membership function (Fig 1).

$$\mu_A(x) = \begin{cases} 0 & \text{for } x < a ; x > c \\ \frac{(x-a)}{(b-a)} & \text{for } a \leq x \leq b \\ \frac{(c-x)}{(c-b)} & \text{for } b \leq x \leq c \end{cases}$$





**Fig. 1. Triangular fuzzy number**

Hwang & Yoon (1981) were the first to develop the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method. The chosen alternative should have the shortest distance from the positive-ideal solution and the farthest distance from the negative-ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes the cost criteria. The negative ideal solution maximizes the cost criteria and minimizes the benefit criteria (Wang & Elhag, 2006). The steps for the Fuzzy TOPSIS method are as follows:

**Step 1:** Feasible alternatives should be generated, evaluation criteria should be decided and the decision makers are to be identified. Let say there are ‘m’ alternatives, ‘n’ criteria and ‘k’ decision makers.

**Step 2:** Allow the decision makers to choose the appropriate linguistic variables to decide about the weightage for the criteria’s ( $\tilde{w}_j$ ). Similarly, make the decision makers to choose the linguistic variables for each alternative with respect to each criterion ( $\tilde{x}_j$ ). The linguistic scale is associated with the standard fuzzy scale in terms of TFN (Chen, 2000).

**Step 3:** Obtain the average weights of criteria and ratings of alternatives given by the ‘k’ decision makers, using Eqs. (i-ii).

$$\tilde{w}_j = \frac{1}{k} [\tilde{w}_j^1 + \tilde{w}_j^2 + \dots + \tilde{w}_j^k] \quad (i)$$

$$\tilde{x}_j = \frac{1}{k} [\tilde{x}_j^1 + \tilde{x}_j^2 + \dots + \tilde{x}_j^k] \quad (ii)$$

where  $\tilde{w}_j$  stands for the weight of criteria and  $\tilde{x}_j$  stands for the rating of alternative given by  $k^{\text{th}}$  decision maker.

**Step 4:** Next step is to make the fuzzy decision matrix of the alternatives (D). This will give the subjective ratings given by a set of decision makers as shown in Eq. (iii).

$$D = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1j} & \tilde{x}_{1m} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \dots & \tilde{x}_{nj} & \tilde{x}_{nm} \end{bmatrix} \quad (iii)$$

where  $\tilde{x}_{ij}$ ,  $j = 1, 2, \dots, m$ , are linguistic variables. The variables are represented by Triangular Fuzzy Numbers,  $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ .

**Step 5:** Normalized fuzzy decision matrix should be constructed using matrix (D). The various criteria scales are transformed to comparable scale using linear scale transformation. The normalized fuzzy decision matrix is given by Eqs. (iv-v).

$$\tilde{r}_{ij} = \left( \frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+} \right), c_j^+ = \max_i c_{ij} \quad (\text{Benefit Criteria}) \quad (iv)$$

$$\tilde{r}_{ij} = \left( \frac{a_j^-}{c_{ij}^-}, \frac{a_j^-}{b_{ij}^-}, \frac{a_j^-}{a_{ij}^-} \right), a_j^- = \min_i a_{ij} \quad (\text{Cost Criteria}) \quad (v)$$

**Step 6:** Calculate the weighted normalized decision matrix ( $\tilde{v}_{ij}$ ) by multiplying the criteria weights ( $\tilde{w}_j$ ) to the elements ( $\tilde{r}_{ij}$ ) of the normalized fuzzy decision matrix as shown in Eq. (vi).

$$\tilde{v}_{ij} = \tilde{r}_{ij} * \tilde{w}_j \quad (vi)$$

**Step 7:** Determine the Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS).

Calculate the separation measures for each alternative. The separation from the positive ideal solution ( $S^+$ ) is given by Eq. (vii).

$$S_i^+ = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^+) \quad (vii)$$

Similarly, the separation from the negative ideal solution ( $S^-$ ) is given by Eq. (viii).

$$S_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-) \quad (viii)$$

Here  $d_v(\dots)$  represents the distance between two fuzzy numbers using the vertex method. According to the vertex method, the distance between two triangular fuzzy numbers  $A_1 (l_1, m_1, u_1)$  and  $A_2 (l_2, m_2, u_2)$  is calculated using Eq. (ix).

$$d(A_1, A_2) = \sqrt{\frac{1}{3} [(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]} \quad (ix)$$

**Step 8:** Calculate the relative closeness to the ideal solution  $C_i^*$  using Eq. (x) and select the option with  $C_i^*$  closest to 1.

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-} \quad (x)$$

#### 4. CASE STUDY

The paper intends to suggest the best new product idea for a bus body building industry. Based on the customers’ requirements, the company came up with three new product ideas. This ideas (alternatives) were : Concept A - Dynamic

and Fluidic (A1), Concept B - Rugged-Robust-Loud & Bold Face (A2), Concept C - Clean and Understated with Subtle Form (A3). The criteria's which affected the decision making were: Aesthetics (C1), Productionising of new product (C2), Cost of product (C3), Regulatory requirements (C4) and Market segment (C5). The decision making process involved three decision makers namely: Design Manager (DM1), Production Manager (DM2) and Marketing Manager (DM3).

**Step 1:** There were three alternatives (A1, A2, A3), five criteria's (C1, C2, C3, C4, C5) and three decision makers (DM1, DM2, DM3).

**Step 2:** The three decision makers gave the weightages for each criteria as well as assigned the linguistic variable for each alternative against each criteria. Standard fuzzy scale was used to convert the linguistic data to Triangular Fuzzy Number (refer Tables I~III).

**TABLE 1: Fuzzy ratings for linguistic variables**

TRIANGULAR FUZZY NUMBER	ALTERNATIVE ASSESSMENT	CRITERIA WEIGHTS
(1,1,3)	Very Poor (VP)	Very Low (VL)
(1,3,5)	Poor (P)	Low (L)
(3,5,7)	Fair (F)	Medium (M)
(5,7,9)	Good (G)	High (H)
(7,9,9)	Very Good (VG)	Very High (VH)

**TABLE 2: Linguistic rating for weightages**

CRITERIA		DECISION MAKERS		
		DM1	DM2	DM3
C1	AESTHETICS	VH	M	VH
C2	PRODUCTIONISING	H	VH	L
C3	COST OF PRODUCT	M	L	VH
C4	REGULATORY REQUIREMENT	H	VL	M
C5	MARKET SEGMENT	M	L	VH

**TABLE 3: Linguistic rating for alternatives against each criterion given by decision makers.**

ALTERNATIVE RATINGS									
CRITERIA	A1			A2			A3		
	DMI	DM2	DM3	DMI	DM2	DM3	DMI	DM2	DM3
C1	G	G	F	VG	G	P	G	G	F
C2	F	G	G	G	G	G	F	F	F
C3	G	G	G	G	G	G	G	F	G
C4	G	P	F	G	F	F	G	F	F
C5	VG	F	P	G	G	F	F	F	P

**Step 3:** Get the average weights of criteria and ratings of alternatives given by the k decision makers.

**Step 4:** Construct the fuzzy decision matrix as shown in table 4.

**TABLE 4: Aggregated ratings for alternative against criteria**

CRITERIA	ALTERNATIVES		
	A1	A2	A3
C1 (5.67, 7.67, 8.33)	(4.33, 6.33, 8.33)	(4.33, 6.33, 7.67)	(4.33, 6.33, 8.33)
C2 (4.33, 6.33, 7.67)	(4.33, 6.33, 8.33)	(5.00, 7.00, 9.00)	(3.00, 5.00, 7.00)
C3 (3.67, 5.67, 7.00)	(5.00, 7.00, 9.00)	(5.00, 7.00, 9.00)	(4.33, 6.33, 8.33)
C4 (3.00, 4.33, 6.33)	(3.00, 5.00, 7.00)	(3.67, 5.67, 7.67)	(3.67, 5.67, 7.67)
C5 (3.67, 5.67, 7.00)	(3.67, 5.67, 7.00)	(4.33, 6.33, 8.33)	(2.33, 4.33, 6.33)

**Step 5:** Construct normalized fuzzy decision matrix (refer Table 5).

**TABLE 5: Normalized fuzzy decision matrix**

CRITERIA	ALTERNATIVES		
	A1	A2	A3
C1	$(2(0.520, 0.760, 1.000))$	$((0.520, 0.760, 0.920))$	$2(0.520, 0.760, 1.000)$
C2	$(0.481, 0.703, 0.925)$	$(0.555, 0.777, 1.000)$	$(0.333, 0.555, 0.777)$
C3	$(0.866, 0.619, 0.481)$	$(0.866, 0.619, 0.481)$	$(0.999, 0.684, 0.519)$
C4	$(0.391, 0.651, 0.912)$	$(0.478, 0.738, 0.999)$	$(0.478, 0.738, 0.999)$
C5	$(0.440, 0.680, 0.840)$	$(0.520, 0.760, 1.000)$	$(0.280, 0.520, 0.760)$

**Step 6:** Calculate the weighted normalized decision matrix (refer Table 6).

**TABLE 6: Weighted normalized fuzzy decision matrix**

CRITERIA	ALTERNATIVES		
	A1	A2	A3
C1	$((2.949, 5.829, 8.333))$	$(2.949, 5.829, 7.664)$	$(2.949, 5.829, 8.333)$
C2	$(2.085, 4.454, 7.102)$	$(2.406, 4.923, 7.670)$	$(1.443, 3.517, 5.966)$
C3	$(3.180, 3.510, 3.370)$	$(3.180, 3.510, 3.370)$	$(3.670, 3.879, 3.640)$
C4	$(1.173, 2.823, 5.777)$	$(1.434, 3.199, 6.327)$	$(1.434, 3.199, 6.327)$
C5	$(1.615, 3.857, 5.882)$	$(1.909, 4.311, 7.003)$	$(1.028, 2.950, 5.322)$

**Step 7:** The FPIS is taken as:  $A^* = (9.000, 9.000, 9.000)$  and the FNIS is taken as:  $A^- = (1.000, 1.000, 1.000)$  (refer table 7).

**TABLE 7: Separation measures for each alternative**

CRITERIA	A1		A2		A3	
	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS
C1	3.963	5.191	4.019	4.883	3.963	5.191
C2	4.902	4.097	4.541	4.541	5.668	3.224
C3	5.648	2.357	5.648	2.357	5.271	2.731
C4	6.050	2.954	5.717	3.337	5.717	3.337
C5	5.498	3.286	5.041	3.993	6.156	2.738
$\sum d$	26.0616	17.8842	24.967	19.110	26.7752	17.2217

**Step 8:** Finally, the closeness coefficient was calculated and the ranking were carried out. It was observed that alternative 2 was the best among the three alternatives (refer Table 8).

**TABLE 8: Relative closeness to the ideal solution**

A1	0.407	2
A2	0.4336	1
A3	0.3914	3

## 5. CONCLUSION

In this paper, MADM approach is presented for initial idea screening of a new product for a bus body building industry under fuzzy environment using Fuzzy TOPSIS. The approach consists of three steps. In step 1, the new product ideas (alternatives) and criteria based on which decisions are to be taken were identified. These alternatives were : Concept A - Dynamic and Fluidic (A1), Concept B - Rugged-Robust-Loud & Bold Face (A2), Concept C - Clean and Understated with Subtle Form (A3). The criteria's which affected the decision making were: Aesthetics (C1), Productionising of new product (C2), Cost of product (C3), Regulatory requirements (C4) and Market segment (C5). In step 2, decision makers who can contribute meaningfully, provide the linguistic ratings for criteria weightages as well as linguistic ratings for alternatives against each criterion. The decision making process involved three decision makers namely: Design Manager (DM1), Production Manager (DM2) and Marketing Manager (DM3). In step 3, fuzzy TOPSIS was applied to aggregate the ratings and generate an overall performance score for selecting the best new product idea. The highest score alternative is selected. In the case study, Alternative 2 (Concept B - Rugged-Robust-Loud & Bold Face) was the best among the three alternatives, followed by Alternative 1 (Concept A - Dynamic and Fluidic).

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# A Fuzzy AHP Approach to Select and Prioritize Strategic Knowledge Management Enablers in Manufacturing Organization

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**Abstract:** Selecting process of a Strategic KMEs has been a very important issue for companies for years because the improper selection of a KME might cause many problems affecting negatively on productivity, precision, flexibility and company's responsive manufacturing capabilities. On the other hand, selecting the best KMEs from its increasing number of existing alternatives in the market are multiple-criteria decision making (MCDM) problem in the presence of many quantitative and qualitative attributes. Therefore, in this paper, an analytic hierarchy process (AHP) is used for the selection and prioritization problem due to the fact that it has been widely used in evaluating various kinds of MCDM problems in both academic researches and practices. However, due to the vagueness and uncertainty on judgments of the decision-maker(s), the crisp pair wise comparison in the conventional AHP seems too insufficient and imprecise to capture the right judgments of decision-maker(s). That is why; fuzzy number logic is introduced in the pair wise comparison of AHP to make up for this deficiency in the conventional AHP. Shortly, in this study, an intelligent approach is proposed, where both techniques; fuzzy logic and AHP have come together, referred to as fuzzy AHP.

**Keywords:** Strategic KMEs, Fuzzy logic, Analytic hierarchy process (AHP)

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## 1. INTRODUCTION

Knowledge is the most valuable resource in helping organizations to sustain competitive advantages, firms are considering adopting KM initiatives to promote the sharing, and creation of knowledge to develop more competitive situations and attain their organization goals (Bhosale and Kant, 2016). In India organizations are trying to implement knowledge management in manufacturing organization from the last two decades. But the success rate is negligible because of lack of proper methodology as well as organizations don't know the penetration of knowledge enablers in their organization. In literature, there has not yet been encountered a study which determines the effect of KMEs penetration on knowledge management performance and organizational performance in different organizations. Therefore, a research has been conducted for such a decision problem in this study. In this research, the Fuzzy AHP methods have been applied to prioritize KMEs. The significance of criteria has been determined by using the fuzzy AHP method. Application of MCDM methods in different fields of knowledge is increasing and new techniques are invented to help decision experts achieving an optimized solution and getting reliable and facilitated route to final decision. The fuzzy AHP is the most popular and validated method for finding weight. There are massive information and undetermined situations which affect decision process and evidently its outcomes. Therefore, to improve decision preciseness and to overcome vagueness in uncertain environments, fuzzy theory and newly intuitionist

fuzzy approaches try to get more reliable solutions. The fuzzy set theory was introduced by Zadeh, (1965) to overcome this vagueness, ambiguity and subjectivity of the human judgment process.

## 2. FUZZY AHP METHODOLOGY

Fuzzy AHP methodology is used for to rank the organizations as per the KMEs penetration in their organization.

### 2.1 Elements of Fuzzy Set Theory

Usually, decision makers are frequently faced with confusions, and difficulties while dealing with the decision making problems due to the involvement of the subjectivity and uncertainty situation in the multi-criteria decision making process. To overcome this vagueness, ambiguity and subjectivity of the human judgment process, fuzzy set theory has been introduced (Zadeh 1965). The word "fuzzy" imply "vagueness". Fuzziness exit when the boundary of a piece of information is not clear. Fuzzy set allows the gradual assessment of the membership of elements in the set, described with the help of membership function valued in the real unit interval  $[0, 1]$ . Decision makers express their opinions in terms of linguistic scales. Linguistic data's are converted into fuzzy numbers with the help of different membership functions. Then, it becomes easy to solve multi-criteria decision making problems. It represents the grade of any element  $x$  of  $X$  that have the

partial membership to  $A$ . A fuzzy set contains elements that have different degrees of membership in it. A fuzzy number is a special fuzzy set  $F = \{(x, \mu_f(x)), x \in R\}$  where  $x$  takes its values on the real line,  $R: -\infty \leq x \leq \infty$  and  $\mu(x)$  is a continuous mapping from  $R$  to the closed interval  $[0, 1]$ . A triangular fuzzy number denoted as  $M = (a, b, c)$ , where  $a \leq b \leq c$  has the following triangular type membership function as shown in Figure 1.

Triangular approximation of fuzzy operations provides fuzzy solutions with much smaller spread than trapezoidal

membership functions as proposed by Buckley (1985). A character tilde ' $\sim$ ' is placed above a symbol if the symbol represents a fuzzy set.

$$\mu_{\tilde{f}}(x) = \begin{cases} 0 & x < a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0 & x > c \end{cases}$$

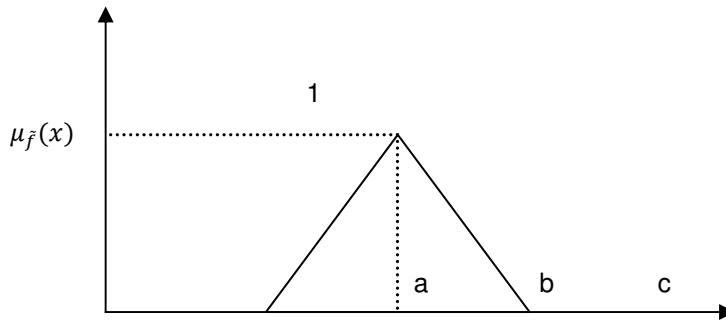


Fig. 1. Triangular fuzzy number

## 2.2 Fuzzy AHP method

The AHP is a flexible multi-criteria decision-making method which can be used to effectively synthesize the judgments given by a team of respondents in order to make better decisions in complex settings, where both tangible and intangible criteria must be considered (Saaty 1990). It is a powerful decision-making methodology for determining the priorities among different criteria. However, the conventional AHP may not be able to truly reflect human cognitive processes-especially in the situations where problems are not fully defined and/or solving these problems involves uncertain data (so-called 'fuzzy' problems). The shortcomings of AHP are generally considered to be as follows, ranking of the AHP is not precise because its discrete scale cannot reflect the human thinking style. In order to deal with ambiguity and uncertainty in the result, Laarhoven and Pedrycz (1983) introduced the concept of 'fuzzy theory' to AHP assessments.

The computational procedure of this approach has been summarized as follows:

**Step 1** Build the structure model.

**Step 2** Defining scale of relative importance used in the pair wise comparison matrix

In order to take the imprecision of human qualitative assessments into consideration; the five triangular fuzzy numbers are defined with the corresponding membership function as shown in table 1.

TABLE 1: The fuzzy linguistic scale for criteria weight

Intensity of Importance	Fuzzy No.	Definition	Membership function
1	$\tilde{1}$	Equally important	(1,1,3)
3	$\tilde{3}$	Moderately more important	(1,3,5)
5	$\tilde{5}$	Strongly more important	(3,5,7)
7	$\tilde{7}$	Very strongly more important	(5,7,9)
9	$\tilde{9}$	Extremely more important	(7,9,11)

Alternatively, by defining the interval of confidence level  $\alpha$ , the triangular fuzzy number is characterized as:

$$\tilde{M}_\alpha = [\alpha^\alpha, c^\alpha] = [(b-a)\alpha] + a, -(c-b)\alpha + c \quad (1)$$

$0 < \alpha \leq 1$  The  $\alpha$ -cut values and index of optimism  $\mu$  incorporated to take care of the accuracy of the measurement.  $\alpha$ -cut is known to incorporate the respondents or decision maker(s) confidence over his/her preference or the judgements. It will yield an interval set of

values from a fuzzy number. Triangular fuzzy numbers ( $\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}$  and  $\tilde{9}$ ) are used to indicate the relative strength of each pair of variables in the same hierarchy.

**Step 3** Develop the fuzzy comparison matrix (FCM).

By using triangular fuzzy numbers, via pair wise comparison, the fuzzy judgment matrix  $\tilde{A} = (\tilde{a}_{ij})$  is constructed as given below:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \tilde{a}_{13} & \dots & \tilde{a}_{1(n-1)} & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \tilde{a}_{23} & \dots & \tilde{a}_{2(n-1)} & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ \tilde{a}_{(n-1)1} & \tilde{a}_{(n-1)2} & \tilde{a}_{(n-1)3} & \dots & 1 & \tilde{a}_{(n-1)n} \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \tilde{a}_{n3} & \dots & \tilde{a}_{n(n-1)} & 1 \end{bmatrix}$$

Where  $\tilde{a}_{ij} = 1$ , If  $i$  equals to  $j$  and  $\tilde{a}_{ij} = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$  or  $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$  if  $i$  is not equal to  $j$ .

**Step 4** Estimating the degree of optimism for  $\tilde{A}$

Degree of satisfaction for the judgment matrix  $\tilde{A}$  is estimated by the index of optimism  $\mu$ . The larger value of the index  $\mu$  indicates the higher degree of optimism (Lee et al.1999). The index of optimism is a linear convex combination defined as:

$$a_{ij}^{\alpha} = \mu \tilde{a}_{iju}^{\alpha} + (1 - \mu) \mu \tilde{a}_{ijl}^{\alpha} \quad \text{where, } 0 < \mu \leq 1 \quad (2)$$

The  $\alpha$ -cut fuzzy comparison matrix converted into their crisp comparison matrix  $A$  by plugging the value of  $\mu$  in equation (2).

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & & \vdots \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}$$

**Step 5** Calculate the maximum Eigen value ( $\lambda_{max}$ ) of the matrix by using equation (3)

$$Aw = \lambda w \quad (3)$$

Where  $w$  is Principal Eigen vector of the matrix

**Step 6** Check the consistency ratio (CR).

The CR is used to determine directly the consistency of pair wise comparisons and expressed by the following equation. In expression the value of random index (RI) depends on the order of matrix (Saaty 1980).

$$CR = \frac{CI}{RI} \quad (4)$$

Where, CI is consistency index and which can be expressed by as follow

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

If the  $CR < 0.10$ , then only consistency of matrix is considered as acceptable, otherwise decision maker has to revise the original values in the pair wise comparison matrix.

**Step 7** Calculate the weight of criteria's.

The weight of each criterion will be calculated by normalizing any of the rows or columns of matrix  $A$ .

**Step 8** Prioritize the criteria's.

The final weight of each criterion can be obtained by multiplying the ratio weight of sub criteria by major criteria's weight. With respect to final weight priorities the criteria.

### 2.3. Methodology of case study

#### 2.3.1 Identification of the Strategic Enablers of KM Adoption in manufacturing and Structure Decision Hierarchy

**Step 1:** Establish Decision Group. A decision group of expert panel which comprising senior managers and , senior executives of manufacturing organizations, is formed.

**Step 2:** Identify the Criteria's and Creating Hierarchical Structure. In this step, the enablers of strategic KM adoption in manufacturing are figured out based on the extensive literature review and discussion with decision group as shown in table 2. Initially the decision problem decomposes into hierarchy with goal at top, major criteria and sub criteria at levels and sub levels. Then approve the decision hierarchy by discussing with the experts.

**TABLE 2: KMEs and literature support**

Major Enabler	Sub Enabler	Authors
Strategic KMEs (STKME)	Organization Goal (STKME1)	Heisig ( 2009 ), Akhavan et al., (2006)
	Top Management Support (STKME2)	Lee et al. (2012), Kamhawi (2012)
	Strategic Planning (STKME3)	Kant and Singh (2009), Akhavan and Jafari (2006)
	Performance Measurement (STKME4)	Jain and Jeppesson (2013), Kant and Singh (2009)
	Collaboration (STKME5)	Machua and Costa (2012), Kamhawi (2012),
	Std.KM Process (STKME6)	Anantatmula and Kanungo (2010), Heisig (2009)

### 3. SELECTION OF THE ALTERNATIVE

**Step 1:** Determine matrix of pair wise comparisons of alternatives for each major and sub criteria for fuzzy AHP method.

The major criterion and sub criterion are compared by respondents using the fuzzy scale (see Table 3). The individual respondents opinions (in the form of fuzzy number  $\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ ) were recorded in such a way that the respondents do not know the opinion of another respondent, and these values were aggregated, hence trying to reduce the bias. The fuzzy judgement matrix for major criterion (see Table 3) was prepared by respondent.

**TABLE 3: FCM for major criteria**

STKM Es	STKM E1	STKM E2	STKM E3	STKM E4	STKM E5	STKM E6
STKM E1	1	$\tilde{1}^{-1}$	$\tilde{3}$	$\tilde{1}^{-1}$	$\tilde{3}$	$\tilde{5}$
STKM E2	$\tilde{1}$	1	$\tilde{3}$	$\tilde{1}^{-1}$	$\tilde{5}$	$\tilde{7}$
STKM E3	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}^{-1}$	$\tilde{3}$	$\tilde{5}$
STKM E4	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	1	$\tilde{9}$	$\tilde{9}$
STKM E5	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{9}^{-1}$	1	$\tilde{3}$
STKM E6	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{3}^{-1}$	1

**Step 2:** Estimation of degree of optimism for judgment matrices

The triangular membership function and  $\alpha$ -cuts (with  $\alpha = 0.5$ ) are used to convert the subjective judgment of decision makers into fuzzy judgments. By using equation (1) lower limit and upper limits of the fuzzy numbers are defined.

$\tilde{1}_\alpha = [1, 2]$	$\tilde{1}_\alpha^{-1} = [1/2, 1]$	$\tilde{1}_\alpha = 1.5$	$\tilde{1}_\alpha^{-1} = [0.75]$
$\tilde{3}_\alpha = [2, 4]$	$\tilde{3}_\alpha^{-1} = [1/4, 1/2]$	$\tilde{3}_\alpha = 3$	$\tilde{3}_\alpha^{-1} = [0.375]$
$\tilde{5}_\alpha = [4, 6]$	$\tilde{5}_\alpha^{-1} = [1/6, 1/4]$	$\tilde{5}_\alpha = 5$	$\tilde{5}_\alpha^{-1} = [0.208]$
$\tilde{7}_\alpha = [6, 8]$	$\tilde{7}_\alpha^{-1} = [1/8, 1/6]$	$\tilde{7}_\alpha = 7$	$\tilde{7}_\alpha^{-1} = [0.145]$
$\tilde{9}_\alpha = [8, 10]$	$\tilde{9}_\alpha^{-1} = [1/10, 1/8]$	$\tilde{9}_\alpha = 9$	$\tilde{9}_\alpha^{-1} = [0.112]$

Using values of these fuzzy numbers into the 'FCM for major criteria' which in table 3, the fuzzy comparison matrix for major criteria are as follow. From equation (2), transform this fuzzy group comparison matrix into a group crisp comparison matrix (GCCM) which in turn helps to determine the weights of the major criteria for KMEs. Here, the value of consistency index ( $\alpha$ ) is taken as 0.5. Hence,

using values from the above FCM main into the equation (2), GCCM for major criteria are as follow:

	1	0.75	3	0.75	3	5
	1.5	1	3	0.75	5	7
	0.375	0.375	1	0.75	3	5
	1.5	1.5	1.5	1	9	9
GCCM=	0.375	0.2085	0.375	0.112	1	3
	0.2085	0.145	0.2085	0.112	0.375	1
Sum of Column $\Rightarrow$	4.9585	3.9785	9.0835	3.475	21.375	30

**Step 3:** Solution of fuzzy Eigen values

The Eigen values of that matrix (GCCMmaj) are calculated and results as follow:

In this all Eigen values we find:  $\lambda_{\max} = \lambda_1 = 6.47$

**Step 4:** Determination of weights for criteria

Using  $\lambda$  value, CR has been calculated using equations (4) and (5). The calculation of CR for matrix (GCCMmaj) is as follow:

Here  $\lambda_{\max} = \lambda_1 = 6.47$  and  $n = 6$  (order of matrix) so,

$$CI = \frac{6.47 - 6}{6 - 1} = 0.094 \quad (6)$$

Where, Random Index (RI) and  $N$  = Order of matrix

N	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

By putting the value of CI from (6) into equation, the CR value for major criteria is as follows.

$$CR = \frac{0.094}{1.25} = 0.075$$

Here,  $CR < 0.1$  for matrix (GCCM) so the comparison of major criteria is acceptable, but if somehow it fails to fulfill the condition for the consistency, then decision makers have to repeat the pair wise comparison process until the condition for consistency has been reached. After the consistency test for matrix, normalization of the GCCMmaj is done. The final weight of the sub criteria can be calculated by multiplying the respective major KMEs weight and ratio weight of each KME.

**After this each element divide by its corresponding sum, we get**

0.201674	0.188513	0.330269	0.215827	0.140351	0.166667
0.302511	0.251351	0.330269	0.215827	0.233918	0.233333
0.075628	0.094257	0.11009	0.215827	0.140351	0.166667
0.302511	0.377027	0.165135	0.28777	0.421053	0.3
0.075628	0.052407	0.041284	0.032374	0.046784	0.1
0.042049	0.036446	0.022954	0.032374	0.017544	0.033333



**4. Calculate the weight of criteria:** Summing up the elements of row and divide them by order of the matrix or no. of element of we get, major criteria weights:

0.207217
0.261202
0.308916
0.058079
0.058079
0.030783

Final priority of Strategic KMEs has been shown in the table 4

**TABLE 4: Final priority of Strategic KMEs**

Main criterion	Sub criteria. Code	CR	Ratio weight	Rank
Strategic KMEs	STKME 1	0.064	0.207	3
	STKME 2		0.261	2
	STKME 3		0.308	1
	STKME 4		0.058	5
	STKME 5		0.133	4
	STKME 6		0.030	6

#### 4. CONCLUSION

From the fuzzy AHP result, it can be concluded that 'Strategic planning (STKME3)' having highest priority weight (0.308) and seem to be a most significant KME among all selected KMEs followed by 'Top management support (STKME2)' (0.261), 'Organization goal (STKME1)' (0.207). 'Std. KM process (STKME6)' seems to be least significant KME among all the selected KMEs. So, while implementation if management accounts this priority of strategic KMEs then results are bound to be fruitful in terms of organizational performance.

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# Application of MCDM in Sourcing Decisions of Manufacturing Sector: A Fuzzy SAW and TOPSIS Approach

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**Abstract:** This study explores a methodical approach to make or buy decision problem by using Multi Criteria Decision Making (MCDM) methods under fuzzy condition. The study is conducted to help a local company operating in the manufacturing sector on their sourcing decision (make or buy) of a new product. The proposed approach employs fuzzy Simple Additive Weighting method (SAW) and TOPSIS to solve make or buy decision problem.

**Keywords:** fuzzy SAW, Make or Buy, Sourcing Decisions, TOPSIS, MCDM, Multi Criteria Decision Making, Manufacturing Sector.

## 1. INTRODUCTION

Make or buy decision (also known as sourcing decision) is one of the crucial issues faced by today's organizations to meet with the increasing demands, political and environmental issues, intensified competition, and technological advancements. Make or buy decision plays an important role on the organizations' success, by determining total costs, profitability, investment decisions, operational effectiveness, corporate strategy, customer services, flexibility, and core competency (Humphreys et al., 2000; Tayles & Drury, 2001). This decision requires consideration of several conflicting criteria ranging from technological to environmental, from strategic to operational and from quantitative to qualitative factors.

## 2. LITERATURE REVIEW

The main struggle in analytically modelling strategic decisions lies in their dependence on quantitative and qualitative information of multiple dimensions. It has been recognised that human assessment on qualitative attributes is always subjective and thus imprecise.

For such decisions, fuzzy approaches allow more accurate description of the decision-making process by incorporating it in the decision process as it considers human subjectivity rather than applying merely objective probability means.

Due to the imprecise and subjective nature of make-or-buy decisions, our approach incorporates fuzzy condition to comprise human judgment on expected benefits, risks, and costs of alternative strategies. The methodology employs trapezoidal fuzzy numbers (TrFN). The membership function of a trapezoidal fuzzy number is as shown (Fig. 1)

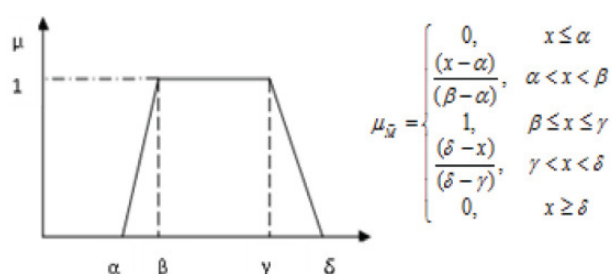


Fig. 1. The membership functions of the trapezoidal fuzzy number

## 3. RESEARCH METHOD

The proposed approach consists of two stages. The first stage employs fuzzy Simple Additive Weighting method (SAW) to evaluate the weights of the considered criteria and the decision matrix, while in the second stage, Technique for Order Preference by Similarity to Identical Solution (TOPSIS) is used to solve the make or buy decision problem.

## 4. STAGE I: EVALUATION OF WEIGHTS AND DECISION MATRIX

The Simple Additive Weighting (SAW), is the simplest and still the widest used MCDM method. Here, SAW is used under Fuzzy conditions to evaluate the weights of various criteria.

### 4.1 Determination of the Hierarchical Structure of Several Criteria and Sub-Criteria

The factors affecting the make or buy decision on which the experts have reached the consensus are listed and are classified. A list of four main criteria namely Operational, Technical, Financial, and Strategic factors which had

profound impact the decision structure were chosen. The list of main criteria and sub criteria in the hierarchical structure is as shown. (Table I)

**TABLE I: List of main criteria and sub criteria for Make or Buy decision**

Main Criteria		Sub-Criteria	
C ₁	Operational Factors	C ₁₁	Lead Time
		C ₁₂	Surety of delivery in Time
		C ₁₃	Volume Flexibility
		C ₁₄	After-sales Service
C ₂	Technical Factors	C ₂₁	Production Capacity
		C ₂₂	Equipment availability
		C ₂₃	Product Quality
		C ₂₄	Design Flexibility
		C ₂₅	Product Development
C ₃	Financial Factors	C ₃₁	Unit Profit
		C ₃₂	Capital Cost
		C ₃₃	Inventory Cost
		C ₃₄	Transportation Cost
C ₄	Strategic Factors	C ₄₁	Company Image
		C ₄₂	Core Competency
		C ₄₃	Competitive Strategy
		C ₄₄	Risks
		C ₄₅	Opportunities

#### 4.1 Determination of the Degree of Importance of the Decision-Makers

Depending on the degree of importance of the decision makers, the problem can be solved by either homogeneity or heterogeneity principle. Homogeneity principle assumes equal importance of decision makers, while under heterogeneity principle; the weights are assigned to the decision makers depending on their degree of importance.

With the consensus of all decision makers in the problem, all decision-makers are considered equal in importance, which refers to a homogeneous group. Therefore, the weights of decision maker are taken as equal  $I_1 = I_2 = I_3 = 1/3$ .

#### 4.2 Definition of Linguistic Scale and Computation of Aggregated Fuzzy Weights of Individual Criteria

The linguistic scales used by decision-makers to assess the importance of attributes and the ratings of alternatives are listed in Table II and Table III, respectively (Deng et al., 2011).

**TABLE II: Fuzzy numbers and linguistic variables for the importance of criteria**

Linguistic Variable	Trapezoidal Fuzzy numbers
Very low (VL)	(0, 0, 0.1, 0.2)
Low (L)	(0.1, 0.2, 0.2, 0.3)
Medium Low (ML)	(0.2, 0.3, 0.4, 0.5)
Medium (M)	(0.4, 0.5, 0.5, 0.6)
Medium High (MH)	(0.5, 0.6, 0.7, 0.8)
High (H)	(0.7, 0.8, 0.8, 0.9)
Very High (VH)	(0.8, 0.9, 1, 1)

**TABLE III: Fuzzy numbers and linguistic variables for the ratings of alternatives**

Linguistic Variable	Trapezoidal Fuzzy numbers
Very Poor (VP)	(0, 0, 1, 2)
Poor (P)	(1, 2, 2, 3)
Medium Poor (MP)	(2, 3, 4, 5)
Medium (M)	(4, 5, 5, 6)
Medium Good (MG)	(5, 6, 7, 8)
Good (G)	(7, 8, 8, 9)
Very Good (VG)	(8, 9, 10, 10)

After deciding on linguistic scale, the evaluation matrix of main attributes is constructed by collecting the linguistic assessments of weights from decision makers and by assigning a corresponding fuzzy number for each evaluation. The resulting matrix is presented below (Table IV). Next, the aggregated fuzzy weights for each criteria and sub-criteria are obtained by using the eq. (ii).

$$W_j = (I_1 \otimes W_{j1}) \oplus (I_2 \otimes W_{j2}) \dots \oplus (I_k \otimes W_{jk}) \quad (ii)$$

where  $W_{jt}$  is, the weight assigned to criteria j by decision maker t, given by eq. (iii):

$$W_{jt} = (a_{jt}, b_{jt}, c_{jt}, d_{jt}) = \{1, 2, \dots, n\}, \quad t = \{1, 2, \dots, k\}. \quad (iii)$$

**TABLE IV: The evaluation of the weights of the main attributes**

Criteria	DM ₁	DM ₂	DM ₃	DM ₁	DM ₂	DM ₃
C ₁	MH	MH	H	(0.5, 0.6, 0.7, 0.8)	(0.5, 0.6, 0.7, 0.8)	(0.7, 0.8, 0.8, 0.9)
C ₂	H	H	VH	(0.7, 0.8, 0.8, 0.9)	(0.7, 0.8, 0.8, 0.9)	(0.8, 0.9, 1.0, 1.0)
C ₃	MH	MH	M	(0.5, 0.6, 0.7, 0.8)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)
C ₄	H	VH	VH	(0.7, 0.8, 0.8, 0.9)	(0.8, 0.9, 1.0, 1.0)	(0.8, 0.9, 1.0, 1.0)

**De-Fuzzifying the Fuzzy Weights of Individual Criteria, Computation of The Normalized Weights**

After assessments are collected from experts, aggregated normalized fuzzy weights are computed and de-fuzzified. Resulting aggregated and normalized fuzzy weights for main criteria are listed below (Table V). The de-fuzzification of  $W_j$ , denoted as  $d(W_j)$ , is given by eq. (iv):

$$d(W) = \frac{(a_j + b_j + c_j + d_j)}{4} \quad j = \{1, 2, \dots, n\} \quad (\text{iv})$$

The crisp value of the normalized weight for attribute  $C_j$ , denoted as  $W_j$ , is given by eq. (v):

$$W_j = \frac{d(W_j)}{\sum_{i=1}^n d(W)} \quad j = \{1, 2, \dots, n\} \quad (\text{v})$$

**TABLE V: Aggregated fuzzy weights of criteria and corresponding normalized weights**

Criteria	Aggregated Fuzzy Weights	De-fuzzified	Normalised
$C_1$	(0.57, 0.67, 0.73, 0.83)	0.70	0.24
$C_2$	(0.73, 0.83, 0.87, 0.93)	0.84	0.28
$C_3$	(0.43, 0.53, 0.57, 0.67)	0.55	0.18
$C_4$	(0.77, 0.87, 0.93, 0.97)	0.88	0.30

The weight vector of main attributes is then calculated as  $W = [0.24, 0.28, 0.18, 0.30]$

Similarly, the normalized aggregated fuzzy weights for sub-criteria are calculated (Table VI).

**TABLE VI: Evaluation of sub-criteria and corresponding normalized aggregated fuzzy weights**

Sub-criteria	DM ₁	DM ₂	DM ₃	Aggregated Fuzzy Weights	De-fuzzified	Normalised
$C_{11}$	MH	H	M	(0.53, 0.63, 0.67, 0.77)	0.650	0.22
$C_{12}$	VH	VH	VH	(0.80, 0.90, 1.00, 1.00)	0.925	0.31
$C_{13}$	H	H	H	(0.70, 0.80, 0.80, 0.90)	0.800	0.27
$C_{14}$	M	MH	MH	(0.47, 0.57, 0.63, 0.73)	0.600	0.20
$C_{21}$	VH	VH	H	(0.77, 0.87, 0.93, 0.97)	0.883	0.26
$C_{22}$	H	H	MH	(0.63, 0.73, 0.77, 0.87)	0.750	0.22
$C_{23}$	MH	H	MH	(0.57, 0.67, 0.73, 0.83)	0.700	0.20
$C_{24}$	M	MH	MH	(0.47, 0.57, 0.63, 0.73)	0.600	0.17
$C_{25}$	M	M	M	(0.40, 0.50, 0.50, 0.60)	0.500	0.15
$C_{31}$	H	VH	H	(0.73, 0.83, 0.87, 0.93)	0.842	0.30
$C_{32}$	M	MH	MH	(0.47, 0.57, 0.63, 0.73)	0.600	0.21
$C_{33}$	H	MH	H	(0.63, 0.73, 0.77, 0.87)	0.750	0.26
$C_{34}$	MH	MH	MH	(0.50, 0.60, 0.70, 0.80)	0.650	0.23
$C_{41}$	ML	ML	M	(0.27, 0.37, 0.43, 0.53)	0.400	0.12
$C_{42}$	M	M	MH	(0.43, 0.53, 0.57, 0.67)	0.550	0.17
$C_{43}$	VH	VH	H	(0.77, 0.87, 0.93, 0.97)	0.883	0.27
$C_{44}$	H	H	MH	(0.63, 0.73, 0.77, 0.87)	0.750	0.23
$C_{45}$	MH	H	MH	(0.57, 0.67, 0.73, 0.83)	0.700	0.21

**4.5 Assessment of Aggregated Fuzzy Ratings of The Alternatives**

The alternatives available for this problem are Make ( $A_1$ ), Subcontracting ( $A_2$ ) or Buy ( $A_3$ ). The alternative Make( $A_1$ ) refers to manufacturing the product in inhouse facility. The

remaining two alternatives Subcontracting ( $A_2$ ) and Buy ( $A_3$ ) differ slightly from each other. The alternative Buy ( $A_3$ ) refers to buying off the shelf from the market and use it in your own product whereas the alternative Subcontract ( $A_2$ ) refers to buying a product manufactured by different

firm on order tailored to the given specifications, needs and requirements.

The evaluation matrix of alternatives against the defined criterion is constructed by collecting the linguistic assessments of ratings from decision makers and by assigning a corresponding fuzzy number to each evaluation. The three decision makers are given equal importance under homogeneity principle. The decision-makers in the committee assess the fuzzy benefits associated with the three alternatives versus the determined criteria. Fuzzy ratings of alternatives with respect to individual main criteria are then computed using theeq. (vi).

$$x_{ij} = \left\{ \frac{r_{ij}}{\max_i d_{ij}} \right\} \otimes 100 \quad (\text{vi})$$

where  $r_{ij}$  is the benefit associated with alternative  $i$  for attributes  $j$ .

In the analysis, all the criteria are treated as benefit-attribute and cost-attributes are converted into the benefit-attributes by reversing assigned values on the verbal scale. The fuzzy aggregated ratings of alternatives against the main criteria are calculated and listed below (Table VII) followed by the defuzzified values. (table VIII).

**TABLE VII: Fuzzy evaluation matrix of the alternatives**

	C ₁	C ₂	C ₃	C ₄
W _i	(0.57, 0.67, 0.73, 0.83)	(0.73, 0.83, 0.87, 0.93)	(0.43, 0.53, 0.57, 0.67)	(0.77, 0.87, 0.93, 0.97)
A ₁	(76.15,87.10,92.45,100.0)	(74.71,85.71,90.05,98.90)	(60.70,75.43,78.88,92.55)	(67.60,80.00,87.93,95.72)
A ₂	(54.24,65.20,70.54,81.49)	(54.16,65.15,70.29,80.73)	(34.13,48.86,55.01,69.74)	(45.68,58.07,62.14,80.25)
A ₃	(63.14,74.09,79.69,90.64)	(62.94,73.93,79.15,90.14)	(51.28,66.01,74.59,89.32)	(62.02,74.41,80.73,91.65)

**TABLE VIII: Defuzzified Decision Matrix**

	C ₁	C ₂	C ₃	C ₄
Weights	0.24	0.28	0.18	0.30
A ₁	88.92	87.34	76.89	82.81
A ₂	61.54	67.58	51.93	61.54
A ₃	77.20	76.54	70.30	77.20

## 5. STAGE II: MAKE OR BUY DECISION USING TOPSIS

The Technique for Order Preference by Similarity to Identical Solution (TOPSIS; Hwang and Yoon, 1981) is based on the concepts that the chosen alternative should have the shortest Euclidean distance from best (ideal) solution and the farthest from worst (negative-ideal) solution. The ideal solution is a hypothetical solution for

which all criteria values corresponds to the maximum criteria values in the database comprising the satisfying solutions; the negative ideal solutions the hypothetical solution for which all criteria values corresponds to the minimum criteria values in the database. TOPSIS thus gives a solution that is not only closest to the hypothetically best, that is also the farthest from hypothetically worst.

### 5.1 Normalising the Decision Matrix

First, all the values in the decision matrix obtained (Table VIII) need to be normalized using the expression given below in eq. (vii)

$$d_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^3 a_{kj}^2}} \quad i = \{1, 2, 3\}, \quad j = \{1, 2, \dots, 4\}, \quad k = \{1, 2, 3\}. \quad (\text{vii})$$

The normalised decision matrix is then weighted by multiplying it by the weight  $w_j$  of the  $j^{\text{th}}$  criterion. This weighted normalized decision matrix is given below (Table IX).

**TABLE IX: Weighted Normalised Decision Matrix**

	C ₁	C ₂	C ₃	C ₄
A ₁	0.1928	0.1572	0.1820	0.1189
A ₂	0.1433	0.1200	0.1408	0.0803
A ₃	0.1797	0.1359	0.1595	0.1087

### 5.2 Determination of the Ideal A* and Negative-Ideal A⁻ Solution

The preferred alternative is the one having the shortest distance from an ideal solution A* and the farthest distance from a negative-ideal solution A⁻. The fictitious alternative A* can be obtained by taking from each criterion the best performance value among all the alternatives; conversely, the negative-ideal solution A⁻ is composed of the worst performances. The ideal and negative ideal solution are as listed (Table X).

**TABLE X: Weighted Ideal A* and negative-ideal A⁻ solutions**

	C ₁	C ₂	C ₃	C ₄
A ⁺	0.1928	0.1572	0.1820	0.1189
A ⁻	0.1433	0.1200	0.1408	0.0803

### 5.3 Identification of The Best Alternative

Each alternative A_i (i= 1, 2, 3), A⁺, A⁻ can be geometrically represented as a point in a four-dimensional space where the generic  $j^{\text{th}}$  axes measure the weighted normalized

performance of that alternative according to criterion  $C_j$  ( $j = 1, 2, \dots, 4$ ). Therefore, it is possible to calculate the Euclidean distances  $S_i^*$  and  $S_i^-$  of each alternative  $A_i$  from the ideal and negative-ideal solutions  $A^*$  and  $A^-$  respectively. The method defines relative closeness of alternative  $A_i$  to the ideal solution for the following ratio  $C_i^* = S_i^- / (S_i^- + S_i^*)$  (Table XI).

**TABLE XI: Absolute  $S_i^*$ ,  $S_i^-$ , and relative  $C_i^*$  distances for each alternative**

	$S_i^*$	$S_i^-$	$C_i^*$
$A_1$	0	0.0838	1
$A_2$	0.0838	0	0
$A_3$	0.0351	0.0523	0.5884

For  $A_i = A^-$ , results  $S_i^- = 0$  and then  $C_i^* = 0$ . For  $A_i = A^+$ , vice versa,  $S_i^* = 0$  and then  $C_i^* = 1$ . The final ranking of the alternatives is made by considering the  $C_i^*$  value for each one. The preferred solution is that having the maximum  $C_i^*$  value.

## 6. RESULTS, CONCLUSIONS AND FUTURE SCOPE

As seen from Table XI, when the  $C_i^*$  values of the alternatives are arranged in the descending order, the largest value is obtained for the alternative of “Make” which is followed by “Buy” and “Subcontracting” alternatives sequentially.

In other words, the best make-or buy decision is found as manufacturing the product in inhouse facility.

In the future course of action, more factors like political factors that includes local govt schemes, tax rebate/incentives, scope for expansion etc need to be considered. Sensitivity analysis on various factors, or on importance of decision makers can be performed.

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# Optimization of Sequential Drilling Operation: Using a Real Coded Genetic Algorithm Approach

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**Abstract:** This paper gives an efficient solution procedure of the real coded Genetic algorithm for the hole making operations where precedence of sequence is required. This paper deals with the optimization of hole-making operations in conditions where a hole may need several tools to get completed. The objective of interest in the considered problem is to minimize the tool airtime. This objective is affected by the sequence through which each operation of each hole is done. The problem is formulated as a mathematical model. The paper includes an illustrative example which shows the application of the proposed algorithm to optimize the sequence of hole-making operations. The performance of the proposed algorithm is tested through solving application example. The computational result conducted in this research indicates that the proposed method is both effective and efficient.

**Keywords:** Hole-making operations, Optimization, real coded genetic algorithm.

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## 1. INTRODUCTION

Hole-making operations such as drilling, reaming, and tapping compose a large portion of machining processes for many industrial parts. For a part with many holes, a particular tool may be required by several holes and also tools of different diameters may be used to drill a single hole to its final size. To reduce tool traverse, it may be suggested that the spindle should not be moved until a hole is completely drilled using several tools of different diameters. This however will lead to excessive tool switches. By the same token, though tool switches can be reduced by completing all operations on all the holes that require the current tool, the travel time will be increased. Furthermore, the amount of tool movement and the number of tool switches will depend on which set of tools are to be used to drill each hole to its final size. The machining cost and tool cost are affected by the selection of tool combination for each hole. Hence, the proper determination of the operations sequence and the corresponding machining speed used to perform each operation are crucial in reducing the total cost of production. Merchant (1985) reported that tool movement and switching time take 70% of the total time in a manufacturing process, on average. Therefore, optimization of hole-making operations can lead to significant reduction in machining time which directly improves productivity of manufacturing systems.

Kolahan and Liang (2000) used a tabu-search approach to minimize the total processing cost for hole-making operations. They considered tool travel time, tool switching time and the cutting time and used the tabu-search algorithm to find the solution. Kenneth et al. (2002), suggested an algorithm for minimizing the non-productive time or airtime for milling by optimally connecting

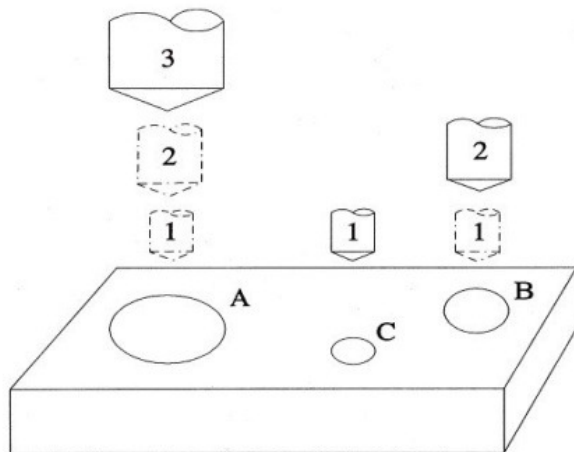
different tool path segments. This problem formulated as a generalized traveling salesman problem with precedence constraints and is solved using a heuristic method. A new approach based on particle swarm optimization (PSO) has been developed by Onwubolu and Clerc (2004) for solving the drilling path optimization problem. Ghaiebi and Solimanpur (2007) used an ant algorithm to solve the proposed mathematical model for optimization of hole-making operations in conditions where a hole may need several tools to get completed. The objective of interest in the considered problem is to minimize the summation of tool airtime and tool switch time. This objective is affected by the sequence through which each operation of each hole is done. Nasiruddin Khan et al. (2010) provides an efficient solution procedure of the TSP for the sequential and non-sequential drilling process on a circuit board, first there is an algorithm for finding an open path when the sequence is not important, then there is an application of the same algorithm which gives the sequence of all operations for hole making on a circuit board in such a way that the total cost is minimum. In that research authors used concept of combination of cycles at its minimal cost, with the discussion of the example which shows the efficiency of the algorithm by considering the cost of the time while changing the tool and tool travel cost so that the total cost is minimized.

Therefore, it is necessary to determine the order by which a particular hole should be drilled by a specific tool in order to minimize the summation of tool airtime. It is notable that the sequence of holes still needs to be optimally determined even if each hole requires only a single tool to be made. The present work is focused on the formulation of the model and proposes real coded genetic algorithm approach to

solve the optimization of hole-making problem. The objective is to minimize production cost which consists of tool travel cost.

## 2. PROBLEM DEFINITION

To make a complete hole, tools with different sizes may be needed. This is specially a must when the diameter of the hole to be made is large. In this case, the hole is initially made using the small-sized tools and then it is enlarged to the size of interest using the large-sized tools. The selection of the set of tools and their sequence can directly affect the machining time and cost. It is common in practice that several holes need a particular tool and a hole may need different tools. The time needed to move from a hole to one another is called as *airtime*. To minimize tool *airtime*, it may be initially thought that a hole should be completed through different tools before movement into another hole. However, this may result in excessive tool switches and thus increments in tool switch time. On the other hand, one may decide to process all the holes which need the tool currently in use. Although, this decision will decrease the tool switch time, it can result in a huge increment in tool *airtime*.



**Fig. 1. A schematic representation of alternative sets of tools for hole making**

For each hole in Fig. 1 the largest tool, shown by solid lines, has to be used to drill the hole to its final size. Some pilot or intermediate tools, shown by dashed lines, may also be used. For instance, for hole A, there could be four different sets of tools; {1,2,3}, {2,3}, {1,3}, and {3}. The selection of tool set for each hole directly affects the required number of tools switches, and tool travel distance. It is notable that the sequence of holes still needs to be optimally determined even if each hole requires only a single tool to be made. The present work is focused on the formulation of the model and proposes real coded genetic algorithm approach to solve the optimization of hole-making problem. The objective is to minimize production cost which consists of tool travel cost.

The cost components considered in this paper include:

**Tool travel cost:** This is the cost of moving the tool from its previous location to the current drilling position. Tool travel cost is proportional to the distance required for the spindle to move between two consecutive drilling locations (Kolahan et al, 2000).

## 3. PROBLEM FORMULATION

The objective of interest in this paper is to minimize the tool *airtime* to reduce tool travel cost which affect the production cost. To minimize the production cost, the following model can be formulated (Kolahan et al, 1996).

$$\text{Min } y = \sum_{i=1}^k \sum_{j=1, j \neq i}^k [a P_{ij}]$$

The following notation are used in the proposed mathematical model.

*i* = tool type index, *i* = 1,.....

*j* = hole index, *j* = 1,.....,

*k* = number of possible operations in sequence

*a* = cost per unit non-productive travelling distance in Rs/mm.

*P_{ij}* = non-productive travelling distance between current hole and previous hole in mm.

*y* = summation of travelling cost in Rs.

## 4. OPTIMIZATION TECHNIQUE (RCGA)

Genetic Algorithms (GAs) are adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetic. The basic concept of GAs is designed to simulate processes in natural system necessary for evolution, specifically those that follow the principles first laid down by Charles Darwin of survival of the fittest. As such they represent an intelligent exploitation of a random search within a defined search space to solve a problem.

### 4.1 GA operator

The GA operators are used to perform certain function, which help to produce and select good offspring from, a set of candidate solutions. The various GA operators that are used generally for solving a problem are given below.

### Reproduction

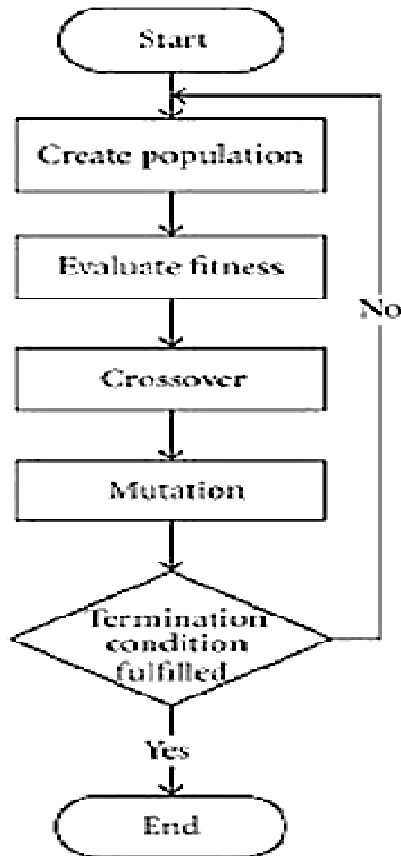
It is usually the first operator applied on a population. Reproduction select good string in a population and form a mating pool. This is why the reproduction operator is sometime known as the selection operator. Selection is the stage of a genetic algorithm in which individual genomes are chosen from a population for later breeding (recombination or crossover).

### Crossover

In the crossover operator, new string are created by exchanging information among strings of the mating pool.



In most crossover operators, two strings are picked from the mating pool at random and some portions of the strings are exchanged between the strings. A single point crossover operator is performed by randomly choosing a crossing site along the string and by exchanging all bits on the right side of the crossing site.



**Fig. 2. Flow Chart For Real Coded Genetic Algorithm**

#### **Mutation**

In genetic algorithms, mutation is a genetic operator used to maintain genetic diversity from one generation of a population of chromosomes to the next. It is analogous to biological mutation. The classic example of a mutation operator involves a probability that an arbitrary bit in a genetic sequence will be changed from its original state. A common method of implementing the mutation operator involves generating a random variable for each bit in a sequence. This random variable tells whether or not a particular bit will be modified. The purpose of mutation in GAs is to allow the algorithm to avoid local minima by preventing the population of chromosomes from becoming too similar to each other, thus slowing or even stopping evolution. Generally GA is used to solve the maximization problem but GA can also handle minimization problems. This can be done by choosing a fitness function suitably (Kumar and Pachauri 2012).

#### **4.2 Parameter Setting**

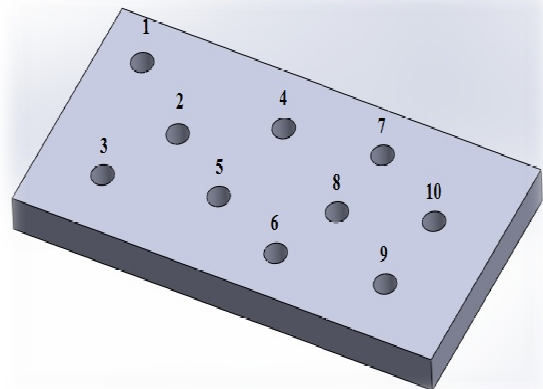
The following parameters as shown in table 1 are set to give better result for optimization of hole-making problem to run RCGA.

**TABLE 1: Parameters set for Real Coded Genetic Algorithm**

S.N	Parameters	Value
1	Population Size	10
2	Crossover Fraction	0.8
3	Mutation Fraction	0.2

#### **5. APPLICATION EXAMPLE**

In this research, application example of M.S. flat plate is considered having dimensions are 200×100×10 mm. The 10 numbers of holes of equal diameter needs to be drilled to manufacture this component having size is 10 mm. There are number of possible sequences are present to drill this holesbut to find the path which is the shortest one is the main aim. The proposed algorithm was coded in C-programme to determine the optimum sequence of drilling operation for the part shown in fig.3.The process parameter selected isa=0.04 Rs/min. The computation is carried out for 10 different starting sequences. To investigate the effect of real coded genetic algorithm on search performance, the search was repeated for optimum result. All types of moulds, moulded parts and plastic moulded goods are the applications of this problems.



**Fig. 3. Top view of example part.**

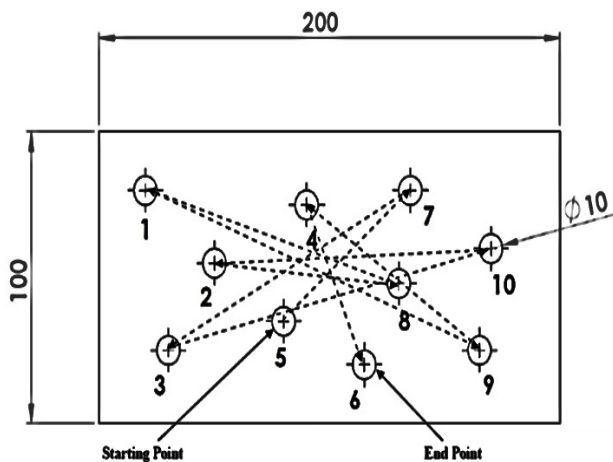
#### **6. RESULTS AND CONCLUSION**

The results thus obtained using existing method is directly compared with the result obtained using c programming of Real Coded Genetic algorithm. Number of iterations are carried out to reach the optimum solution. Therefore, it found that non-productive movements have been reduced appreciably by RCGA compare to Existing method.

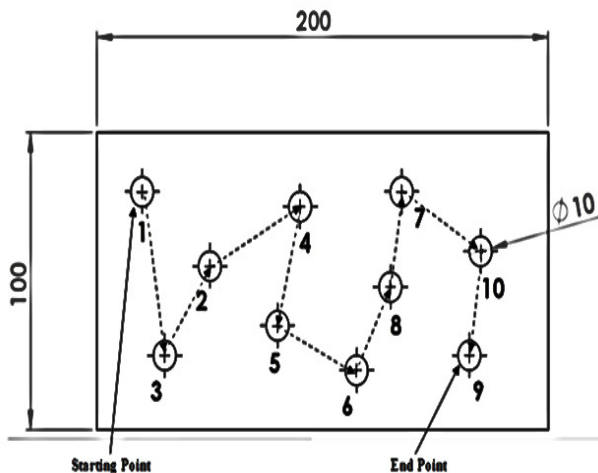
**TABLE 2: Result obtained by using RCGA**

	Sequence	Distance travelled by tool in mm	Cost (y) in Rs
<b>Maximum possible tool travel</b>	5 7 3 10 2 8 1 9 4 6	954.51	38.1804
<b>Optimized tool travel</b>	1 3 2 4 5 6 8 7 10 9	355.79	14.2316

The result obtained by RCGA(a) and Existing method (b) has been shown in Figure 4 &5 in terms of non-productive movement of tool.



**Fig. 4. Sequence with maximum possible cost (5-7-3-10-2-8-1-9-4-6)**



**Fig. 5. Optimized Sequence with minimum cost(1-3-2-4-5-6-8-7-10-9)**

The present work is focused on the formulation of the model and proposes real coded genetic algorithm approach to solve the optimization of hole making problem. In this work real coded genetic algorithm is used to reduce the overall production cost in hole making operations. Obtained results using real coded genetic algorithm shows that the total production cost can be significantly reduced compare to the existing method. It is observed that, the performance of real coded genetic algorithm depends upon algorithm specific parameters such as population size, string length, crossover and mutation probabilities and the number of iterations performed.

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# Selection of Design Parameters of Engine Valves for Design for Remanufacturing by Fuzzy TOPSIS Method

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**Abstract:** Remanufacturing is the activity which combines the profitability and the benefits of the sustainable development, through reducing the landfills and virgin raw material consumption, energy and specialized labour used in production and thus reduces carbon footprint on earth. In Remanufacturing, a remanufactured machine must match the same customer anticipation as new machines. Valves are very important engine components that are used to control the flow and exchange of gases in internal combustion engines. Parameters affecting life of valves are analyzed and its remanufacturing is undertaken. For this purpose, the 6 design parameters are assigned ranks using Fuzzy topsis method by taking opinion from decision makers and averaged for further analysis. On the basis of reviews 6 design parameters for design for remanufacturing of disposal (Visible defects, surface roughness, Dimension changes in height, Dimension changes in diameter (Stem), Dimension changes in diameter (Valve), Ovality) are taken into considerations and 3 decision maker's opinion is taken on impact on valves in different working conditions (inlet valve (hill, coastal and plain area working conditions) and exhaust valve (hill, coastal and plain area working conditions)). Fuzzy topsis method is a mathematical tool for optimization of results and selects the best method to be applied. In this paper the comparative studies show that The highest ranking was given to visual Defects so we conclude that visual Defects is the best Design parameter to give more importance in the design of product followed by Visible defects, Ovality, Dimension changes in diameter (Stem), Dimension changes in height, Dimension changes in diameter (Valve), and the lowest ranking is given to surface roughness.

**Keywords:** Fuzzy TOPSIS, Remanufacturing, Design for Remanufacturing

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## 1. INTRODUCTION

The manufacturing industry has extensively used the resources and energy on the earth in last century thereby causing adverse effects on the environment [Marie et al., 2012]. To reduce its impact Industries are now focusing the products which can be used in multiple life cycle. Many products are recycled or remanufactured to save material as well as energy incorporated in that product [Minjung et al., 2010]. Product design is an area that significantly influences the sustainability of the product. During the course of design, one has to define the structure of product considering the functional definition. Decision taken during design stage has a considerable influence on the entire life cycle strategies used in recovery of the material [Sara et al., 2012]. Remanufacturing is considered to be the most suitable end of life strategy as it combines the benefits of sustainability and profitability of the business [Winifred et al., 2007].

Expenditures like time, energy and cost are avoided in remanufacturing which is a measure concern in recycling, reprocessing and manufacturing [Xiaoyan et al., 2012]. At the same time product returns with full warranty and endures for at least another full life cycle. Valves are most important components of the diesel engine. In the operation

thermal and mechanical stresses are imposed on valve because of high temperature and pressure in the cylinder. Objective of the work is to investigate the design parameters for different condition and suggest a guideline for designer so as to improve the sustainability of valves in all conditions. If designer considers these parameters with the priority suggested, sustainability of the valves will get improved. As there will be less distraction to the component leads to improve efficiency of product recovery as core received in future might be in better condition. There are many methods available which are too complex to understand quantitatively. By using imprecise knowledge use of these methods are usual.

Fuzzy Logic uses human reasoning in imprecise information to generate own decision [Izadikhah et al., 2014]. In classical methods precise values and exact equations are used which required exact understanding of system [Pulkit et al., 2015]. Fuzzy logic permits us to reduce complex system to simple abstraction by using knowledge and experience. Fuzzy logic is widely used in design optimization where fuzzy system is defined by adjustable parameters further subjected maximize performance criteria [Wei et al., 2014; Feng et al., 2014]. Design optimization by fuzzy logic system can be classified structural and parametric design. This can be differentiated

using the set of design parameters we are setting for the system. In case of linguistic importance weighed aggregation ratings are calculated by using symmetric triangular fuzzy numbers [Shanian et al., 2006; Simran et al., 2016]. There are some typical advantages of this approach like small changes in membership function causes small variation in weighted aggregate. In case of non Fuzzy importance weighted aggregate remains stable.

## 2. DESIGN FOR REMANUFACTURING

Design for remanufacturing is the design process where products are designed which facilitates the remanufacturing process or any of step of remanufacturing. Remanufacturing is totally different from the other EOL strategies like repair, refurbishment or reuse as the product is restored to like new condition with reduced waste generation and less resource consumption [Tai et al., 2014; Jianquan et al., 2015]. It leads to higher profit margin for the producers from reduces production cost and benefits realized as environmentally proactive. Still the remanufacturer has to generate the maximum profit as they offer the price of 45 to 60 % of the newly produced components in order to complete the sales of the new product [Golinska et al., 2015]. Remanufacturing oriented design can facilitates the manufacturer to assess the aftermarket benefits as he can sell the product at 60 to 70 % whereas the cost of the remanufactured components are up to 35 to 60% approximately [Vishal et al., 2015].

Main objective of this work is product recovery this can be achieved through the life enhancement or maximum material recovery of component at the end of life [Fulari et al., 2015]. Design for remanufacturing is the best option for product recovery as it recovers material as well as suggest design guideline which protects functionality and quality of product [Cao et al., 2012]. Analyzing the design parameters as well as causes of failure of bearing in perspective of remanufacturing will led to understand possibility of amount of material recovery. In this work firstly design parameters were investigated which affects the end of life situation of ball bearing.

Certainly we can build a link between the critical design parameters and causes of failures so that real effect of the recovery will be cleared. By optimizing the parameters we can enhance the material recovery as well as develop the guideline for designer to enhance life of ball bearing. These guideline will also facilitates designing the components which yields the better recovery option for components. The concept of the design of remanufacturing comes in the focus due to the technical barrier during the process of the remanufacturing and these factors are related back to the design process of the product. Proposed work will integrate the remanufacturing process with the product design and development. Mapping of the remanufacturing activities with the design parameters of the product, for the better

product recovery at the end of life, will provide the suitable design options corresponding to the remanufacturing scenario. This process will certainly improve the sustainability as well as economic gain for remanufacturing at product design level. One cannot achieve the full benefit of the remanufacturing unless connecting product design means design for remanufacturing should be the backbone of the product design and development process. The process of remanufacturing starts with the core collection which is designed for functionality before the manufacturing of the component. Form of the component, material selection and fastening methods affects the efficiency of remanufacturing in later stage. Thus design for remanufacturing plays a vital role in product design process to improve the remanufacturability. Design for remanufacturing will optimize the remanufacturing for better profitability and also help for resolving understanding and awareness of remanufacturing.

## 3. ENGINE VALVES SELECTION FOR ANALYSIS

Intake and exhaust valves are very important engine components that are used to control the flow and exchange of gases in internal combustion engines. Such valves are loaded by spring forces and subjected to thermal loading due to high temperature and pressure inside the cylinder. To figure out the most affected parameter after the lifetime of 4-stroke Diesel Engine Valve (TATA Truck) and to increase effectiveness of remanufacturing process by optimisation of critical parameters. To elaborate the methodology inlet and exhaust valves of a Diesel Engine are taken in to account. Valves are selected from different demographic area like hilly, costal and plain areas. Performance during Life cycle and sustainability of valves throughout the life will be different in these areas due to change in weather and working conditions.

In hilly area valves may get frequent heavy load in dry environment with less air so as in plain area steady load with sufficient air at high speed will be there. In coastal area moisture contents in the air may affect the performance of valves. Due to change in environmental condition there will be scattered effect on design parameters at end of life. At Design stage if also similar design parameters considered for designing valve EOL condition of cores are different due to changes in working conditions. Product sustainability will also different for different areas.

## 4. ANALYSIS AND DISCUSSION

Table 1 shows impact of Different Scrap Valves each denoted with C1, C2...C6⁶. Design parameters are Visible defects, surface roughness, Dimension changes in height, Dimension changes in diameter (Stem), Dimension changes in diameter (Valve), Ovality) denoted by D1, D2...D6⁷

**TABLE 1: Impact of different scrap valves on design parameters**

Impact	Different Scrap Valves	Design parameter	Description
C1	Inlet valve 1(Hill)	D1	Visible defects
C2	Inlet valve 2( Coastal)	D2	surface roughness
C3	Inlet valve 3(Plain)	D3	Dimension changes in height
C4	Exhaust valve 1 (Hill)	D4	Dimension changes in diameter (Stem)
C5	Exhaust valve 2 ( Coastal)	D5	Dimension changes in diameter (Valve)
C6	Exhaust valve 3(Plain)	D6	Ovality

Linguistic variables are assigned for impact of different valves like Negligible important, Low important, Medium low important, Medium important, Medium high important, High important, Very highly important and similarly, linguistic variables are assigned for design parameters like Very highly difference, High difference, Medium high difference, Medium difference, Medium low difference, Low difference, Negligible difference as shown in the Table 2

**TABLE 2: Linguistic variables for criteria and alternatives**

Different Scrap Valves			Design parameter		
	Notation	Fuzzy no.		Notation	Fuzzy no.
Negligible important	NI	(0,0,0.1)	Very highly difference	VHD	(0,0,1)
Low important	LI	(0,0.1,0.3)	High difference	HD	(0,1,3)
Medium low important	MLI	(0.1,0.3,0.5)	Medium high difference	MHD	(1,3,5)
Medium important	MI	(0.3,0.5,0.7)	Medium difference	MD	(3,5,7)
Medium high important	MHI	(0.5,0.7,0.9)	Medium low difference	MLD	(5,7,9)
High important	HI	(0.7,0.9,1)	Low difference	LD	(7,9,10)
Very highly important	VHI	(0.9,1,1)	Negligible difference	ND	(9,10,10)

**TABLE 3: Decision maker's opinion about the impact of different scrap valves**

Methods adopted	DM1	DM2	DM3	Aggregate fuzzy no.
C1	HI	MHI	VHI	(0.7,0.87,0.97 )
C2	MHI	HI	MI	(0.5,0.7,0.87)
C3	LI	MLI	LI	(0.03,0.17,0.37)
C4	VHI	MHI	VHI	(0.77,0.9,0.97)
C5	HI	VHI	MHI	(0.7,0.87,0.97)
C6	MI	LI	MLI	(0.13,0.3,0.5)

In Table 4 decision maker's opinion regarding the different scrap valves wrt to design parameters in order to improve the quality of remanufacturing.

**TABLE 4: Decision maker's opinion about design parameter wrt different scrap valves**

	C1	C2	C3	C4	C5	C6
D1	MHD	HD	LD	HD	VHD	MLD
D2	HD	VHD	MD	VHD	VHD	MD
D3	HD	HD	MLD	HD	HD	MLD
D4	MHD	MHD	MLD	VHD	VHD	MD

<b>D5</b>	HD	VHD	LD	HD	HD	MD
<b>D6</b>	HD	HD	MLD	HD	HD	LD

In Table 5 we assign the fuzzy numbers to the linguistic variables suggested by decision maker in Table 4 on the basis of values given in Table 2.

**TABLE 5: Fuzzy decision matrix**

(1,3,5)	(0,1,3)	(7,9,10)	(0,1,3)	(0,0,1)	(5,7,9)
(0,1,3)	(0,0,1)	(3,5,7)	(0,0,1)	(0,0,1)	(3,5,7)
(0,1,3)	(0,1,3)	(5,7,9)	(0,1,3)	(0,1,3)	(5,7,9)
(1,3,5)	(1,3,5)	(5,7,9)	(0,0,1)	(0,0,1)	(3,5,7)
(0,1,3)	(0,0,1)	(7,9,10)	(0,1,3)	(0,1,3)	(3,5,7)
(0,1,3)	(0,1,3)	(5,7,9)	(0,1,3)	(0,1,3)	(7,9,10)

In Table 6 for calculation of Normalized fuzzy decision matrix each value in Table 5 is divided by 10.

**TABLE 6: Normalized fuzzy decision matrix**

(0.1,0.3,0.5)	(0,0.1,0.3)	(0.7,0.9,1)	(0,0.1,0.3)	(0,0,0.1)	(0.5,0.7,0.9)
(0,0.1,0.3)	(0,0,0.1)	(0.3,0.5,0.7)	(0,0,0.1)	(0,0,0.1)	(0.3,0.5,0.7)
(0,0.1,0.3)	(0,0.1,0.3)	(0.5,0.7,0.9)	(0,0.1,0.3)	(0,0.1,0.3)	(0.5,0.7,0.9)
(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.5,0.7,0.9)	(0,0,0.1)	(0,0,0.1)	(0.3,0.5,0.7)
(0,0.1,0.3)	(0,0,0.1)	(0.7,0.9,1)	(0,0.1,0.3)	(0,0.1,0.3)	(0.3,0.5,0.7)
(0,0.1,0.3)	(0,0.1,0.3)	(0.5,0.7,0.9)	(0,0.1,0.3)	(0,0.1,0.3)	(0.7,0.9,1)

In Table 7, for calculation of weighed normalized fuzzy decision matrix we multiply the values in Table 6 with the aggregated fuzzy no. of its respective column⁹. e.g.: first column of Table 6 is for C1 so values in first column are multiplied by the aggregated fuzzy no for C1 as calculated in table 3 for better understanding consider the following example in above Table 6 first cell shows normalized fuzzy matrix on C1. D1 so for calculation of weighed normalized fuzzy decision matrix for C1. D1 we multiply cell one matrix with aggregated fuzzy number matrix for C1 given in Table 3. Normalized fuzzy decision matrix:(m1,m2,m3); Aggregated fuzzy decision matrix for C1: (w1,w2,w3) therefore, weighed normalized fuzzy decision matrix(x,y,z) is equal to: (x, y, z) = (m1*w1, m2*w2, m3*w3).

**TABLE 7: Weighed normalized fuzzy decision matrix**

(0.07,0.26,0.48)	(0,0.07,0.261)	(0.021,0.153,0.37)	(0,0.09,0.29)	(0,0,0.097)	(0.065,0.21,0.45)
(0,0.087,0.29)	(0,0,0.087)	(0.009,0.085,0.259)	(0,0,0.097)	(0,0,0.097)	(0.039,0.15,0.35)
(0,0.087,0.29)	(0,0.07,0.26)	(0.015,0.119,0.33)	(0,0.09,0.29)	(0,0.087,0.2),	(0.065,0.21,0.45)
(0.07,0.26,0.48)	(0.05,0.21,0.435)	(0.015,0.119,0.33)	(0,0,0.097)	(0,0,0.097)	(0.039,0.15,0.35)
(0,0.087,0.29)	(0,0,0.087)	(0.021,0.153,0.37)	(0,0.09,0.29)	(0,0.087,0.29)	(0.039,0.15,0.35)
(0,0.087,0.29)	(0,0.07,0.26)	(0.015,0.119,0.33)	(0,0.09,0.29)	(0,0.087,0.29)	(0.09,0.27,0.5)

In Table 8, column no.2 shows Fuzzy positive ideal solutions (FPIS D*) and column no.3 shows Fuzzy negative ideal solutions (FNIS D-)

D* can be calculated by following formula:

$$D^* = \sum \frac{1}{2} [\max (|I^{st} - 1|; |I^{rd} - 1|) + (2^{nd} - 1)]$$

Here we consider weighed normalized decision matrix set from table no. 7 and the value greater between  $|I^{st} - 1|$  and  $|I^{rd} - 1|$  is selected and added with  $(2^{nd} - 1)$ .

Now D⁻ is given by:

$$D^- = \sum \frac{1}{2} [\max (|I^{st} - 0|, |I^{rd} - 0|) + |I^{nd} - 0|]$$

Similarly, we find out D- by adding the greater value with 2nd term.

We obtain the Relative Closest Coefficient of Strategies (C*) using the formula,

$$C^* = D^* / (D^* + D^-)$$

So we substitute the above calculated value of D* and D- to calculate C.

Similarly, all C values are calculated and compared. The method with highest C value is ranked 1st and going so on

ranks are assigned to the methods using Fuzzy Topsis.

**TABLE 8: Relative Closest Coefficient of Design Parameters and Ranking**

Design Parameters	D*	D-	$C_i = D_i / (D_i^* + D_i^-)$	Rank
D1	5.5305	1.3655	0.198013341	1
D2	5.815	0.751	0.114377094	6
D3	5.6285	1.2415	0.180713246	4
D4	5.5435	1.2465	0.183578792	3
D5	5.6865	1.122	0.164794007	5
D6	5.586	1.3415	0.193648502	2

## 5. CONCLUSION

Here by using multi criteria decision making Fuzzy topsis tool we gave the order of preference to the design for Remanufacturing selected. The six design parameters related to remanufacturing are assigned ranks using Fuzzy TOPSIS method by taking opinion from decision makers and averaged for further analysis. The highest ranking was given to visual Defects so we conclude that visual Defects is the best Design parameter to give more importance in the design of product followed by Visible defects, Ovality, Dimension changes in diameter (Stem), Dimension changes in height, Dimension changes in diameter (Valve), and the lowest ranking is given to surface roughness as this parameter is having negligible change after the EOL when compare with other design parameters. Hence visible defect is the important parameter to be considered while designing the valve is concluded. Fuzzy Topsis Method can be applied in certain other aspects also to make suitable decisions.

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# A Grey- Based DEMATEL Model for Evaluating Supplier Development Criteria

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**Abstract:** This paper intends to evaluate various Supplier Development (SD) criteria using Grey Decision Making Trail and Evaluation Laboratory (DEMATEL). SD consists of set of activities by buying organization for supplier to enhance supplier performance and its capabilities, which will help to meet supply needs and create favourable results for the buying organization. This study features the role of supplier in adding to the competencies of the manufacturing organization, and interpreted the importance of SD Programs. Through a literature review, 12 criteria for the SD are determined in context of Indian Manufacturing organization. The outcomes of study consist grouping of criteria into cause and effect category. Supplier's past performance, Delivery performance and proximity to manufacturing base are identified as important cause criteria which highly influencing the competitive advantage and productivity improvement of organization.

**Keywords:** Supplier Development, Grey DEMATEL Method, Cause-Effect diagram.

## 1. INTRODUCTION

Since manufacturing firms increasingly focus on their core business activities, an efficient supply chain plays a major role in generating competitive advantages. However, suppliers too often lack the capability to perform adequately. Connecting with reliable and trustworthy suppliers has become a key factor for successful organizations. Therefore, supplier decisions are important, but difficult, due to the challenges firms face in today's business environment (Matook et al., 2009). In response, manufacturers across a wide range of industries are implementing supplier development programs (SDPs) to improve supply chain performance (Wagner, 2011). Supplier development is a critical competitive endeavour for organizations and their supply chains. Investigation into this area has increased over the past few years, yet further understanding of supplier development is needed (Bai and Sarkis, 2016).

## 2. LITERATURE REVIEW

One of the biggest paradigm shifts in modern business management is the fact that currently companies compete not individually among themselves, but in a systemic way within their respective supply chains. Suppliers being the

first and the foremost critical link in any organization exercise a great control in developing supply chain performance by furnishing essential raw materials. Generally, supplier development concentrated on monetary objectives and tried to build up supplier's financial execution and abilities identified with quality, cost, and delivery (Busse et al., 2016).

Buyer organization has to suffer from huge impairment due to impoverished environmental performance of supplier. This poor performance of supplier relating to environment can lead organizations to recall their sold products which increase operational cost, deteriorate organization's prestige and causes decrease in sales (Sancha et al., 2015). SD activities upgrade supplier's social performance and manufacturing organization's operational performance (enhanced quality, diminished cost and delivery time), however does not gives returns for financial outcomes in the short terms.

After literature review, various criteria for the SD are determined, out of which 12 most significant SD criteria are shortlisted with the help of experts from industry and academics. Table 1 shows shortlisted criteria with their description and sources.

TABLE 1: Criteria with Description and Source

Code	Criteria	Description	Source
C1	Supplier Commitment	Commitment assures the healthy relation between supplier and buyer in terms of providing goods and services.	Lu et al. (2012), Routroy and Pradhan (2013)

Code	Criteria	Description	Source
C2	Supplier's Flexibility	To overcome unpredictable situation related to increase in demand or making changes related to products.	Nagati and Rebolledo (2013), Bai and Sarkis (2016)
C3	Competitive Advantage	Best situation any organization is looking for to become advance among its competitors.	Busse et al. (2016), Sancha et al. (2015)
C4	Proximity to Manufacturing Base	Indicates nearness to supplier base for proper sharing of knowledge and information.	Rezaei et al. (2015)
C5	Supplier Rewards and Incentives	One of the important factor, which motivates supplier for continuous growth.	Chidambaranathan et al. (2009)
C6	Long- term Benefits	Various benefits related with the lasting effect on organizational performance.	Dalvi and Kant (2015)
C7	Delivery Performance	It illustrates the ability to company on time delivery of right product to right customers.	Akman (2015), Bai and Sarkis (2016)
C8	Buyer's Top Management Commitment	For the active participation of higher authorities of organization, top management commitment is essential	Mortensen and Arlbjorn (2012), Li et al. (2012)
C9	Productivity Improvement	Nearness to supplier help in on-time data availability.	Rezaei et al. (2015)
C10	High Product Availability	In order to demand of any product during peak period	Dalvi and Kant (2015)
C11	Effective Communication	Sharing of information and knowledge between supplier and manufacturer.	Kumar and Routroy (2014), Praxmarer-Carus et al. (2013)
C12	Supplier's Past Performance	This includes how supplier completed previous assignments.	Dalvi and Kant (2015)

### 3. METHODOLOGY

This study utilizes the grey Decision-Making Trail and Evaluation Laboratory (DEMATEL) method to develop criteria for SD. To handle important and causal relationship between criteria, DEMATEL method is considered as one of the best method (Wu and Lee, 2007). DEMATEL ability to highlight interrelationships between criteria and ranking of criteria helped us to choose DEMATEL approach for our work. DEMATEL is unable to express obscure data and deal with lack of information, uncertain conditions, and clashing opinions. As the human opinions are not definite and complicated, the grey system theory can overcome such problems. All the systems that include uncertainty and many experts or decision makers, the grey system theory is suitable.

#### 3.1 GREY DEMATEL METHOD

In order to attain the advantage of both Grey system theory and DEMATEL method, this study utilizes Grey DEMATEL method. The procedural steps of Grey DEMATEL method is shown below:

**Step 1: Generate the initial direct relation matrices:** Consider the number of respondent is 'L' and number of identified criteria is 'n'. Respondents are asked to make pair- wise comparisons and as a result the direct relation

matrix  $A_{n \times n}$  is produced in which  $a_{ij}^k$  represents the number that shows the impact of criteria i on the criteria j by respondent k. Every respondent is assigned with five scales rating to allocate the relationship between criteria (see Table 2).

**TABLE 2: The Grey Linguistic Rating**

Linguistic variable	Influence Score	Grey Numbers
No influence (No)	0	[0,0]
Very low influence (VL)	1	[0,0.25]
Low influence (L)	2	[0.25,0.5]
High influence (H)	3	[0.5,0.75]
Very high influence (VH)	4	[0.75,1]
Source: Govindan et al., 2016		

**Step 2: Estimate the Grey relation matrices:** This step includes conversion of influence scores to corresponding Grey numbers with their respective lower bounds and upper bounds .i.e.

$$\theta G_{ij}^k = [\underline{G}_{ij}^k, \overline{G}_{ij}^k]$$

The Grey matrix,  $G^k$  called the Grey relation matrix for respondent k.

**Step 3: Estimate average Grey relation matrices:** It is obtained by averaging the opinions of all the respondents using the following equation:

$$G_{ij} = \left[ \frac{\sum_{k=1}^L \underline{G}_{ij}^k}{L}, \frac{\sum_{k=1}^L \bar{G}_{ij}^k}{L} \right] \quad (7)$$

**Step 4: Compute the crisp relation matrix from average Grey relation matrix:** In this method de-greying is applied which is a modification of a de-fuzzification method, i.e. converting fuzzy data into crisp scores (CFCS). Following three procedural steps are as follows:

a) Normalizing the Grey number:

$$\tilde{G}_{ij} = (\underline{G}_{ij} - \min_j \underline{G}_{ij}) / \Delta_{min}^{max} \quad (8)$$

$$\tilde{\bar{G}}_{ij} = (\bar{G}_{ij} - \min_j \bar{G}_{ij}) / \Delta_{min}^{max} \quad (9)$$

where,

$$\Delta_{min}^{max} = \max_j \bar{G}_{ij} - \min_j \underline{G}_{ij} \quad (10)$$

b) Estimating total normalized crisp value:

$$H_{ij} = \frac{(\tilde{G}_{ij}(1 - \tilde{\bar{G}}_{ij}) + (\tilde{\bar{G}}_{ij} \times \tilde{G}_{ij}))}{(1 - \tilde{\bar{G}}_{ij} + \tilde{G}_{ij})} \quad (11)$$

c) Estimating final crisp values:

$$\dot{Y}_{ij} = \min_j \underline{G}_{ij} + H_{ij} \Delta_{min}^{max} \quad (12)$$

and the crisp relation matrix is given by

$$Y = |\dot{Y}_{ij}|$$

**Step 5: Generate the normalized direct crisp relation matrix:** Normalized direct crisp relation matrix, K is estimated by finding P and multiplying average crisp relation matrix Y with P. i.e.

$$P = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n \dot{Y}_{ij}} \quad (13)$$

and

$$K = Y \times P \quad (14)$$

**Step 6: Calculating the total relation matrix:** The total relation matrix T is calculated by using equation given below.

$$T = K(I - K)^{-1} \quad (15)$$

$$T = |t_{ij}|_{n \times n}$$

where,  $1 \leq i \leq n$ ;  $1 \leq j \leq n$ ; I = Identity matrix of order  $n \times n$ .

**Step 7: Attaining the causal diagram and Prioritization of criteria:** To generate the causal diagram, knowledge of two important parameters is necessary i.e. D and R. D represents degree of influential impact and it is calculated by sum of rows, whereas R represents degree of influenced impact and it is calculated by sum of columns. D and R are calculated by using following equations:

$$D = [\sum_{j=1}^n t_{ij}]_{n \times 1} = [t_i]_{n \times 1} \quad (16)$$

$$R = [\sum_{i=1}^n t_{ij}]_{1 \times n} = [t_j]_{1 \times n} \quad (17)$$

(D + R), shows the relative importance of each criteria. It represents the horizontal axis of causal diagram which is called as "Prominence Vector". (D - R), represents the vertical axis of casual diagram which is called as "Relation Vector". The criteria which have negative value of (D - R) comes under effect group, whereas criteria with positive value of (D - R) indicates cause group. After obtaining the causal diagram and identifying the cause and effect group, prioritization of criteria is done by analysing values of prominence vector (D - R). After obtaining the causal diagram and identifying the cause and effect group, prioritization of criteria is done by analysing the values of prominence vector (D + R) which shows the relative importance of each criterion.

#### 4. APPLICATION OF METHODOLOGY

A case study of Indian Manufacturing Industry is selected to demonstrate the utility of proposed methodology. Organization X want to focus on its core business activities, which makes it very much dependent on its suppliers various products. To enhance the performance of supplier, organization is interested in SDPs. A group of 5 experts who are having experience and knowledge in the field of SD are invited to give the influence score to all criteria with respect to each other and to generate five initial direct relation matrices using five point linguistic rating scale from Table 2. Team of experts consists of managers, marketing analyst, and experts from the field from the field of SD. Table 3 shows initial direct relation matrix for 1st expert.

#### 5. RESULTS AND DISCUSSIONS

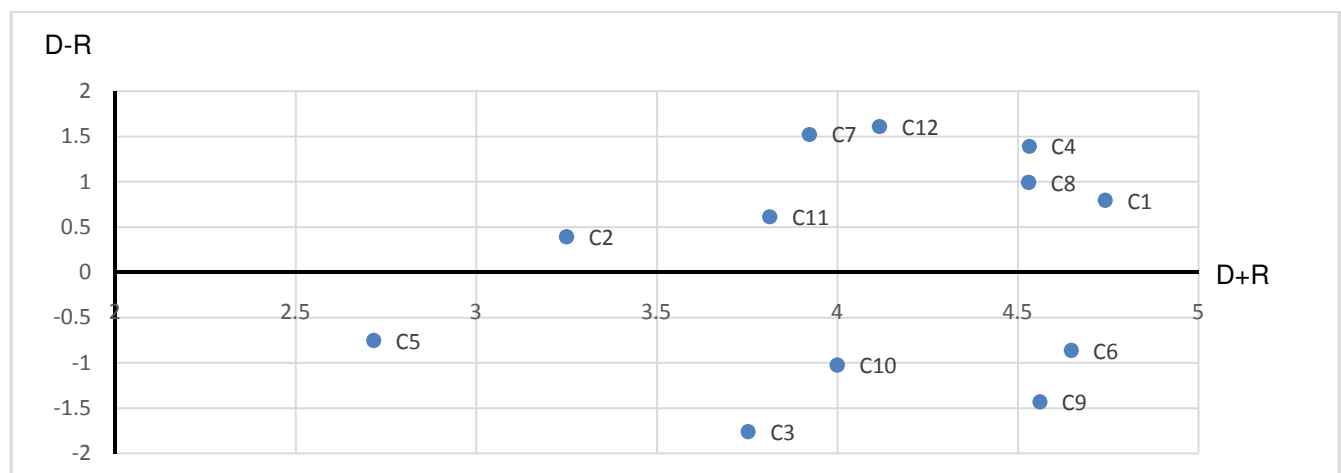
Systematically various steps of methodology are applied and results are shown in Table 4 and cause-effect diagram is plotted shown in Figure 1. Criteria appearing in the cause group have direct impact on the complete system and their directly affect the objectives of the system. Criteria in effect group are easily affected by the criteria of cause group. Supplier's past performance C12, Delivery Performance C7 and Proximity to manufacturing base C4 are cause criteria which highly influencing the competitive advantage and productivity improvement of organization.

**TABLE 3: Initial Direct Relation Matrix for 1st Expert**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0	4	4	3	4	4	2	2	3	3	3	2
C2	2	0	1	2	3	3	1	4	2	0	0	3
C3	3	1	0	0	2	0	1	0	0	1	0	3
C4	3	4	3	0	4	3	0	3	3	4	1	4
C5	3	1	3	1	0	3	3	2	3	0	0	1
C6	3	1	0	1	3	0	3	2	3	3	3	2
C7	4	4	3	0	4	2	0	2	3	3	1	0
C8	1	4	4	4	3	3	4	0	4	3	3	2
C9	0	3	4	1	3	1	0	1	0	4	4	3
C10	1	3	3	3	0	1	3	0	0	0	4	1
C11	2	4	4	2	3	1	4	1	4	2	0	3
C12	3	4	4	2	3	4	3	3	3	2	3	0

**TABLE 4: The Prominence Vector and the Relational Vector**

Criteria	D	R	D+R	D-R
C1	2.7681	1.9728	4.7409	0.7953
C2	1.8213	1.4285	3.2498	0.3928
C3	0.9958	2.7562	3.752	-1.7604
C4	2.9625	1.5683	4.5308	1.3942
C5	0.9807	1.7344	2.7151	-0.7537
C6	1.8926	2.7543	4.6469	-0.8617
C7	2.7234	1.1991	3.9225	1.5243
C8	2.7612	1.7686	4.5298	0.9926
C9	1.5647	2.9954	4.5601	-1.4307
C10	1.4871	2.5127	3.9998	-1.0256
C11	2.2143	1.5984	3.8127	0.6159
C12	2.8643	1.2520	4.1163	1.6123



**Fig. 1. Cause- Effect Diagram**

## 6. CONCLUSIONS

This study highlights the role of supplier in any organization and importance of SDPs. The Grey DEMATEL methodology is implemented to evaluate the criteria for SD. Result shows that out of twelve criteria, seven criteria fall under cause group and five fall under effect group. . Supplier's past performance, Delivery Performance and Proximity to manufacturing base are very crucial criteria cause criteria that affect SD. These results will form as basis for organization to implement SDPs for different suppliers.

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# A Fuzzy AHP-TOPSIS Framework for Pipe Material Selection in Sugar Industry

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**Abstract:** The pipe material selection for sugar industry plays a significant role in an engineering design process. The suitable material selection for pipes in sugar industry is one of the important tasks for the designers. A poorly selected material adds to manufacturing cost and increase the cost unnecessarily, therefore there is a necessity of systematic and efficient approach towards material selection to choose best alternative material for pipes. The aim of this paper is to select the best pipe material in sugar industries. This paper proposes a framework based on fuzzy analytical hierarchy process (AHP) and fuzzy technique for order performance by similarity to ideal solution (TOPSIS) to identify and rank the alternative pipe materials in sugar industry. Also the empirical study is presented to illustrate the proposed method. Total 13 important material properties and 7 stainless steel grades are identified through literature review and finalized through experts' opinion. The result of this study indicates that 'density', 'yield strength', and 'tensile strength' are three most important material properties and SS316, SSJ4 and SS304 stainless steel grades are suitable for pipe material in sugar industries.

**Keywords:** fuzzy AHP, fuzzy TOPSIS, Triangular fuzzy number (TFN), Pipe Materials

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## 1. INTRODUCTION

In the design and development of any structural elements like pipes in sugar industry, material selection is one of the most challenging issues and it is also critical for the success and to meet the demands of cost reduction and better performance. In order to fulfill the pipe material end requirements, designers need to examine the performance of various pipe materials and spot suitable materials with accurate functionalities. Generally, experts are choosing a pipe material for sugar industry by adopting the trial and error methods with investment of enormous cost or build on compilation of past data leading to loss of time (Shanian and Savadogo, 2006). Due to the presence of large number of materials with diverse properties, the pipe material selection in sugar industry is complicated and time consuming task. While selecting alternative pipe materials, a clear understanding of functional needs for each individual component is required and various important criteria's need to be considered. An improper selection can negatively affect productivity, profitability and reputation of an organization (Karande and Chakraborty, 2012). Selecting appropriate pipe material can decrease manufacturing time, increase the efficiency of process and increase productivity (Darji and Patel, 2014). Hence, a systematic and efficient approach to material selection is necessary in order to select the best alternative pipe material in sugar industry. The non commensurable and conflicting nature of the evaluation criteria of pipe material selection can be solved using MCDM method. Wear and corrosion are the most important factors that the surface of the engineering parts like pipes used in sugar industry must confront (Mariajaya and Senthilvelan, 2013).

The rest of the sections are organized as follows. Section 2 briefly reviews the literature on pipe material selection in sugar industry. Proposed methodology is presented in section 3. Section 4 presents the application of fuzzy AHP-TOPSIS method for pipes material selection in sugar industry and finally the results, discussion and conclusions are described in section 5.

## 2. LITERATURE REVIEW

### 2.1 Sugar Industry Pipe Selection

The researchers have made an attempt to reduce the failure rate in the sugar industrial equipment. The many failures were interrupted the production process and create financial impact. Due to this reason for increased machine ideal time, maintenance time and reduce production quality in the sugar industry (Parameshwaran et al., 2015). The following literature are detailed the problems in the sugar industry. (Pravin et al., 2007) reported that, US\$250 million is lost due to corrosion failures in Indian sugar industries. (Wesley et al., 2012) has absorbed, AISI 444 has the better corrosion performance compared to AISI 1010 and similar to AISI 304 grade steel. (Kumar, 2011) has suggested sulphanilamide, sulphapyridine and sulphathiazole as the anticorrosive medium to reduce the corrosion of the process equipment in sugar industries. (Prado et al., 2010) evaluated the effect of sugar cane juice on carbon steel roll and studied the effect of austenitic stainless steel welded carbon steel roll. The main wear mechanism silica is ploughing and cutting the sugar cane roller shell (Casanova and Aguilar, 2008). (Montakarntiwong et al., 2013) have investigated the thermal power plant concretes strength and heat conduction.

## 2.2 Fuzzy AHP-TOPSIS

The AHP is one of the widely used multi criteria decision making methods (MCDM) It structures a decision problem as a hierarchical model consisting of criteria and alternatives. The priority vector needs to be derived from a pair-wise comparison matrix (PCM) that is collected from experts judgments. Extensive studies have been done on how to derive the priority vector from a PCM (Torfi et al., 2010). The various factors are arranged in a hierarchical or a network structure with the objective(s) at the top, followed by one or more layers of criteria, and finally, the alternatives at the bottom. The TOPSIS one of the classic multi-criteria decision making method and was developed by Hwang and Yoon in (1981). It is based on the concept that the selected alternative should have the shortest distance from the positive ideal solution (PIS) and the furthest from the negative ideal solution (NIS). In the traditional formulation of the TOPSIS method, personal judgments are represented with crisp values. But in the real life, measurement by using crisp values is not always possible. The better approach may be to use linguistic value rather than crisp value. Fuzzy set theory can be used to present linguistic value. For this reason, the fuzzy TOPSIS method is very appropriate for solving real life application problems under a fuzzy environment (Karande and Chakraborty, 2012).

## 3. PROPOSED METHODOLOGY

### 3.1 Fuzzy AHP method

Step 1: Establish decision group.

A decision group of experts panel which comprising managers, department representatives, and supervisor is formed.

Step 2: Identify the criteria's and creating hierarchical structure

Initially the decision problem decomposes into hierarchy with goal at top, major criteria and sub-criteria at levels and sub levels.

Step 3: Defining scale of relative importance used in the pair wise comparison matrix.

In this study TFN is used for pairwise comparisons of main criteria as well as sub-criteria.

Step 4: Development of judgment matrices by pair wise comparisons.

In each level, the criteria are compared pair wise according to their levels of influence and based on the specified criteria in the higher level by using triangular fuzzy numbers.

The fuzzy judgement matrix  $\tilde{A}$  is constructed as

$$\tilde{A} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{13} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \vdots \\ \tilde{a}_{n1} & \cdots & \cdots & \cdots & 1 \end{bmatrix} \quad (i)$$

And  $\tilde{a}_{ij} = 1/i = j$ . If  $\tilde{A}_{ij}$  is a matrix value assigned to the relationship of component i to component j, then  $\tilde{A}_{ij}$  is equal to  $1/\tilde{A}_{ji}$

Step 5: Converting the fuzzy comparison matrix into a crisp comparison matrix

Proposed  $\alpha$  cut method used to rank the fuzzy numbers. The  $\alpha$  cut is known to incorporate the  $\alpha$  experts or decision makers confidence over his preference or the judgments.

$$\tilde{A}^\alpha = \begin{bmatrix} 1 & \cdots & \tilde{a}_{13}^\alpha & \cdots & \tilde{a}_{1n}^\alpha \\ \tilde{a}_{21}^\alpha & 1 & \cdots & \cdots & \tilde{a}_{2n}^\alpha \\ \vdots & \vdots & \ddots & \cdots & \vdots \\ \tilde{a}_{n1}^\alpha & \cdots & \cdots & \cdots & 1 \end{bmatrix} \quad (ii)$$

$$\tilde{a}_{ij}^\alpha = \mu \tilde{a}_{iju}^\alpha + (1 - \mu) \tilde{a}_{ijv}^\alpha, \text{ where } 0 < \mu \leq 1 \quad (iii)$$

Step 6 Consistency check and deriving priorities

The consistency can be checked as follows

1. Calculate the largest Eigen value of the matrix by using

$$Aw = \lambda_{\max} w \quad (iv)$$

2. The final consistency ratio (CR), usage of which let someone to conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as indicated.

$$CR = CI/RI \quad (v)$$

$$\text{Where } CI = \frac{\lambda_{\max} - n}{n - 1} \quad (vi)$$

And CR should be less than 0.10. Then it can be said the comparisons are acceptable, otherwise they are not acceptable and should be revised.

Step 7: Calculate the weight of criteria's

The criteria weights can be calculated based on the normalised pair-wise comparison matrix  $A$ . first calculate sum of all the elements in each column, then divide every element of each column by their respective sum of all elements, after that determine the sum of all the elements in each row of the matrix and divide the sum of all elements for each row by the order of matrix and get the weight of corresponding criteria.

### 3.2 Fuzzy TOPSIS method

Step 1: Choose the linguistic rating values for the alternative with respect to criteria

Let us assume there are  $m$  possible alternatives called  $A = \{A_1, A_2, \dots, A_m\}$  which are to be evaluated against the criteria,  $C = \{C_1, C_2, \dots, C_n\}$ . The criteria weights are denoted by  $w_j$  ( $j = 1, 2, \dots, n$ ). The performance ratings of each expert  $D_k$  ( $k = 1, 2, \dots, K$ ) for each alternative  $A_i$  ( $i = 1, 2, \dots, m$ ) with respect to criteria  $C_j$  ( $j = 1, 2, \dots, n$ ) are denoted by  $\tilde{R}_k = \tilde{x}_{ijk}$  ( $i = 1, 2, \dots, m; j = 1, 2, \dots, n; k = 1, 2, \dots, K$ ) membership function  $\mu_{\tilde{R}_k}(x)$ .

Step 2: Calculate aggregate fuzzy ratings for the alternatives

The fuzzy ratings of all experts are described as TFN  $\tilde{R}_k = (a_k, b_k, c_k)$ ,  $k = 1, 2, \dots, K$  then the aggregated fuzzy rating is given by  $\tilde{R} = (a, b, c)$   $k = 1, 2, \dots, K$  where

$$a = \min \{a_k\}, \quad b = \frac{1}{K} \sum_{k=1}^K b_k, \quad c = \max \{c_k\} \quad (\text{vii})$$

The fuzzy ratings of the  $k$ th decision maker are  $\tilde{X}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ ,  $i = 1, 2, \dots, m$ ,  $j = 1, 2, \dots, n$  then the aggregated fuzzy rating  $\tilde{X}_{ij}$  of alternative with respect to each criteria is given by  $\tilde{X}_{ij} = (a_{ij}, b_{ij}, c_{ij})$  where

$$a = \min \{a_{ijk}\}, \quad b = \frac{1}{K} \sum_{k=1}^K b_{ijk}, \quad c = \max \{c_{ijk}\}$$

Step 3: Construct the fuzzy decision matrix

The fuzzy decision matrix for the alternatives ( $\tilde{D}$ ) is constructed as follows:

$$\tilde{D} = \begin{matrix} & \begin{matrix} \tilde{X}_{11} & \tilde{X}_{12} & \dots & \tilde{X}_{1n} \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} \tilde{X}_{21} & \tilde{X}_{22} & \dots & \tilde{X}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{X}_{m1} & \tilde{X}_{m2} & \dots & \tilde{X}_{mn} \end{bmatrix} \end{matrix}$$

$i = 1, 2, \dots, m; j = 1, 2, \dots, n$  (viii)

Step 4: Construct the Normalize fuzzy decision matrix

The raw data is normalized by using linear scale transformation to bring the various criteria scales into a comparable scale. The normalized fuzzy decision matrix  $\tilde{R}$  is given by:

$$\tilde{R} = [r_{ij}]_{m \times n} \quad i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (\text{ix})$$

Step 5: Determine the fuzzy ideal solution (FPIS) and fuzzy negative ideal solution (FNIS)

The FPIS and FNIS of the alternatives is computed as follows:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \dots, \tilde{v}_n^+) \quad \text{where} \quad \tilde{v}_j^+ = (\tilde{c}_j^+, \tilde{c}_j^+, \tilde{c}_j^+) \quad \text{and} \quad \tilde{c}_j^+ = \max \{ \tilde{c}_{ij} \} \quad (\text{x})$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-) \quad \text{where} \quad \tilde{v}_j^- = (\tilde{a}_j^-, \tilde{a}_j^-, \tilde{a}_j^-) \quad \text{and} \quad \tilde{a}_j^- = \min \{ \tilde{a}_{ij} \} \quad (\text{xi})$$

Step 6: Calculate the distance of each alternative from FPIS and FNIS

The distance ( $d_i^+, d_i^-$ ) of each weighted alternative  $i = 1, 2, \dots, m$  from the FPIS and the FNIS is computed as follows:

$$d_i^+ = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^+), \quad i = 1, 2, \dots, m \quad (\text{xii})$$

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1, 2, \dots, m \quad (\text{xiii})$$

Step 7: Calculate the closeness coefficient ( $CC_i$ ) of each alternative

The closeness coefficient  $CC_i$  represents the distances to the fuzzy positive ideal solution ( $A^+$ ) and the fuzzy negative ideal solution ( $A^-$ ) simultaneously. The closeness coefficient of each alternative is calculated as:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}$$

Step 8: Rank the alternatives

In step 8, the different alternatives are ranked according to the closeness coefficient ( $CC_i$ ) in decreasing order.

## 4. APPLICATION OF PROPOSED FUZZY AHP-TOPSIS METHOD

Step 1: Identification of the alternative pipe material in sugar industry

The decision group is composed of the 12 expert which comprising managers, department representatives, and supervisor is formed. In these study 13 pipe material properties is identified through literature review and intensive discussion with decision group members. The 5 expert is formed to evaluate pipe materials against its properties. Total 7 alternative materials are identified through literature review and finalized it by discussion with the expert.

Step 2: Calculate weight of the pipe material properties by fuzzy AHP

In this phase the decision group is asked to make pair wise comparisons of four main properties and 13 sub properties by using linguistic variables. The arithmetic mean of these values is computed to obtain the pair-wise comparison matrixes of criteria and sub-criteria are given in Tables 1. The results obtained from the calculations based on pair-wise comparison matrixes are presented in Table 1. CR values of all the matrixes are less than 0.1; hence, these matrixes are consistent.



**TABLE 1: Final priority of material properties**

Major criterion	Major criterion wt.	Sub criterion	CR	Ratio weight	Final weight	Rank
Mechanical properties	0.5766	Density	0.0483	0.4704	0.27123	1
		Tensile strength		0.2623	0.15120	3
		Yield strength		0.0432	0.2492	2
		Per. Elongation		0.1442	0.08315	6
		Hardness		0.07946	0.0458	8
Thermal properties	0.2548	Thermal Expansion	0.0996	0.5687	0.1449	4
		Thermal conductivity		0.2492	0.06349	7
		Sp. Heat		0.1067	0.02719	10
		Melting point		0.0748	0.01907	11
Chemical properties	0.05042	Corrosion resistance	0.0510	0.9004	0.04539	9
		Wear resistance		0.0995	0.0050	13
Electrical properties	0.11707	Electrical resistivity	0.0913	0.8753	0.1024	5
		Electrical conductivity		0.1246	0.0145	12

Step 3: Pipe material selection in sugar industry by fuzzy TOPSIS

In this study all the properties are the cost criteria. Hence, fuzzy positive-ideal solution (FPIS,  $A^+$ ) and fuzzy negative-ideal solution (FNIS,  $A^-$ ) as  $\tilde{v}^+ = (0,0,0)$  and  $\tilde{v}^- = (1,1,1)$  for all these properties. Then compute the distance  $d_v(.)$  of each alternative from FPIS ( $A^+$ ) and FNIS ( $A^-$ ) using the Eqs. (x), (xi). For example  $d_v(.)$  the distance  $d_v(A_1, A^+)$  and  $d_v(A_1, A^-)$  from FPIS ( $A^+$ ) and FNIS ( $A^-$ ), are computed as follows,

$$d(A_1, A^+) = \sqrt{\frac{1}{3}[(0 - 0.027)^2 + (0 - 0.048)^2 + (0 - 0.27)^2]} = 0.15901$$

$$d(A_1, A^-) = \sqrt{\frac{1}{3}[(1 - 0.027)^2 + (1 - 0.048)^2 + (1 - 0.27)^2]} = 0.89135$$

Similarly, calculations are done for other alternative materials computed the distances  $d_i^+$  and  $d_i^-$ . By using the distances  $d_i^+$  and  $d_i^-$  the closeness coefficient ( $CC_i$ ) of material ssj4 is as,

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} = \frac{0.70651}{0.70651 + 12.36657} = 0.94595$$

Similarly, compute the distances  $d_i^+$  and  $d_i^-$  the closeness coefficient ( $CC_i$ ) for other materials. The final results are summarized in Table 2. Based on the  $CC_i$  value, the ranking the alternatives in descending order.

**TABLE 2: Linguistic scale evaluation matrix for the materials**

	D	TS	YS	%E	H	TE	TC	SH	MP	CR	WR	ER	EC
J4	M	M	VG	P	G	M	VG	M	G	G	G	VP	VP
JSLAUS	G	M	G	M	G	M	M	G	M	G	VG	VP	P
204Cu	G	G	M	G	VG	G	M	M	G	VG	G	P	VP
409M	M	M	G	P	M	P	P	G	M	G	G	P	VP
304	G	G	M	P	G	P	M	G	M	VG	VG	P	P
312A	G	M	G	G	VG	M	M	G	G	G	G	VP	VP
316	M	M	G	M	M	M	G	M	G	VG	G	P	P

**TABLE 3: Fuzzy evaluations matrix for materials**

	D	TS	YS	-	-	-	-	-	-	-	WR	ER	EC
J4	(3,5,7)	(3,5,7)	(7,9,11)								(5,7,9)	(1,1,3)	(1,1,3)
JS LAUS	(5,7,9)	(3,5,7)	(5,7,9)								(7,9,11)	(1,1,3)	(1,3,5)
204Cu	(5,7,9)	(5,7,9)	(3,5,7)								(5,7,9)	(1,3,5)	(1,1,3)
409M	(3,5,7)	(3,5,7)	(5,7,9)								(5,7,9)	(1,3,5)	(1,1,3)
304	(5,7,9)	(5,7,9)	(3,5,7)								(7,9,11)	(1,3,5)	(1,3,5)
312A	(5,7,9)	(3,5,7)	(5,7,9)								(5,7,9)	(1,1,3)	(1,1,3)
316	(3,5,7)	(5,7,9)	(5,7,9)	-	-	-	-	-	-	-	(5,7,9)	(1,3,5)	(1,3,5)

**TABLE 4: Closeness coefficient ( $CC_i$ ) and final ranking of materials**

Alternative Materials	$d_i^+$	$d_i^-$	( $CC_i$ )	Rank
J4	0.70651	12.36657	0.94595	2
JS LAUS	0.83044	12.382592	0.937149	7
SS 204Cu	0.76554	12.38046	0.941766	5
SS 409M	0.791964	12.33162	0.93965	6
SS 304	0.75358	12.407026	0.942739	3
SS 312A	0.756432	12.38898	0.942456	4
SS 316	0.67670	12.427523	0.948359	1

## 5. RESULTS, DISCUSSIONS AND CONCLUSIONS

Through the extensive literature review and discussion with decision group total 13 important material properties and 7 materials for pipes in sugar industry are identified. The study presents a scientific framework for pipe material selection in sugar industry by using hybrid multi criteria technique which combines fuzzy AHP and fuzzy TOPSIS. The weight of the materials properties is calculated by using fuzzy AHP and by using these properties weight the pipe materials in sugar industry is ranked by using fuzzy TOPSIS method. These properties are grouped into four major criteria's as Mechanical properties, Thermal properties, Chemical properties and Electrical properties. It observed from Table 9 that the mechanical properties are uppermost importance among the all major criteria's with weight of a 0.5766. Therefore, the organization should give primary priority for these properties. Thermal properties are also higher weight (0.2548), followed by Electrical properties to weight of 0.11707. The mechanical property 'Density' is having highest among all properties (sub-criteria) is shown in Table 9. Density is an intensive property of material. The 'yield strength' is ranked at second position in the list; It supports the force incurred during use in the industry. 'Tensile strength' is at third position; The fuzzy TOPSIS results are as shown in above table. According to the  $CC_i$  value the ranking of the materials are 316- J4- 304- 312A- 204Cu- 409M-JS LAUS from most important to least. Material 316 is at highest

rank, J4 at second rank, 304 is ranked third, 312A is ranked fourth, 204Cu is ranked fifth and 409M and JS LAUS is at least position. Hence organization should implement these materials as per the ranking

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# Simulation and Optimization of Spur Gear Parameters Using Taguchi Method

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**Abstract:** Gear is one the most vital components in mechanical power transmission system. Hence, a design is required which reduces failure in gear. In the present work, the design parameters of spur gear like face width, module and number of teeth are optimized to obtained minimum value of bending stress by selecting suitable orthogonal array and conducting experiments under taguchi method. The results obtained are validated by finite element analysis.

**Keywords:** Spur gear, Taguchi method, FEA.

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## 1. INTRODUCTION

The history of gears is probably as old as civilization itself. Even today, the importance of gears in the manufacturing industry is undiminished and continues to grow. Gears are wheel-like machine elements that have teeth uniformly spaced around the outer surface of the blank. Gears deliver force (torque) and motion (rpm) from one part of a machine to another. Failure can occur in various modes. If care is taken during design stage itself to prevent each of these failures a sound design can evolve. Gear design calculations and experimental test are necessary to develop and confirm a hypothesis for the probable cause of failure. It is that pitting is the reason for gear failure. 60% of failure is only due to pitting. So there is necessary to reduce the pitting. So there is necessary to reduce the pitting to achieve maximum life. Exceeding limiting values of bending stress will result into pitting and reduce the life. These stresses should minimize to get maximum life.

## 2. LITERATURE

Murali Mohan et al. Performed the optimization of spur gear consider the objective function as weight, tooth deflection and centre distance and the module, face width and number of the on pinion, are as decision variables and subjected to constraints namely, bending stress, contact stress. Because of multi-objective function with constraints is very difficult to optimize using conventional optimization techniques, used non-traditional optimization technique called genetic algorithm. The objective of spur gear design here are minimize weight of the meshing gear set minimize tooth deflection. Module, face width and number of teeth on pinion, are design variable of spur gear set, minimizing the centre distance, weight and objective function taken as tooth deflection of gears.

Rathore. Generally observed the gear failed due to fatigue. Due to minor drop in bending stress it reduces the life of

spur gear. Gear fails due to the tensile fatigue condition. More practical approach of gear design to changed gear parameters like pressure angle, asymmetric teeth and root fillet curve. Interchange ability of such parameter do not assure the existing the gear design. Worked on the stress relieving features by provided the circular holes on it. Used the finite element method for analysis and compared with the analytical curve alteration. Work completed on the optimum size and stress relieving features of various sizes are inserted on gear teeth at root.

Aziz et al. Gear tends to play a very vital role in all industries. Article review the methodology used to investigate bending strength of spur gear. Finite element method (FEM), analytical calculation and investigational techniques were used carried to understand the bending strength spur gear. The method was used with different type of equations and standards to obtained gear failures. The most common method used to find out the bending strength by the numerical calculation. Next very important step was used as finite element method for simulation and later used for data verification with each other. The most important stage used to put the gears to physical experiment and validated all data from the numerical calculation and FEM method. Kanata et al. Gear used as the most critical components in mechanical power transmission. Iterative approach required to optimize the design parameter. Gears failure affected the power transmission system. To overcome such type of problem studied the root causes of gear failure and tried to eliminate such causes. Bending and contact stresses were the basic causes of spur gear failure. An attempt made minimise the stress by modifying the face width, module and pressure angle of spur gear. The stresses were analytically calculated using Lewis equation. Optimization tools like finite element analysis were used to optimize the design parameter of spur gear. It was observed that, the maximum bending and contact stresses were decreased while increasing face width, module and

recommendable to use optimal values of tooth parameters during design work. Such stress reduction improved their pitting resistance and prolonged the service life.

Gupta. Gears are one of important modes for transmission of mechanical power in different mechanical system. Weight and volume were reduced by optimization method to increase the service life and good bearing capacity. Gear parameter module, no of teeth on the pinion considered as design variable and objective function considered as centre distance. The bending stress limit and the surface stress limit were considered as the constraints. The optimization technique Genetic Algorithm technique of optimization used to obtain the optimized values of module and number of teeth on the pinion and the results were compared with obtained using the traditional method. Fesharaki et al. Studied, the general form of objective function and design constraints for the minimize the volume and weight of a gearbox. Taken objective function and constraints used in gearbox ratio for different stages. Gear box weight or volume reduced by mat lab programme with different stages of gear box selected. Finally, by chooses different values for the input power, gear ratio and hardness of gears the practical graphs from the results of the optimization are presented. From the graphs, all the necessary parameters of the gearbox such as number of stages, modules, face width of gears, and shaft diameter can be derived. The results are compared with those reported in the previous works and an example presented to show how the practical graphs can be used.

Faruk Mendi et al. Performed, motion and force transmitting gear box component optimized by the modern optimization technique genetic algorithm for dimensional optimization. Gearbox shaft, gear and optimal rolling bearing optimized. The best result were obtained from the genetic algorithm within the space where it performed by design constraints. Load carried by the optimized dimensional components. The results obtained by genetic algorithm optimization were compared to those obtained by analytical methods. These obtained results indicate that genetic algorithm can be used reliably in machine element design problems. Niles Pedersen et al [8]. Strength of gear influences by geometry. Two modes of failure studied bending stress and contact stress determine the strength of gear. Generally primary fails due to the pitting, while former of tooth breakage. Work focused on reducing bending stress level with improving the gear strength. Taken consideration of design gears strength parameter. Almost all gears exhibit involute shape because the contact forces act along a straight line and a center distance variation due to, e.g. manufacturing tolerances or loading, does not influence this fact. A center variation will neither influence the gear ratio. The only design variable that controls the involute shape is the pressure angle  $\alpha$ ; it is typically assigned the value  $\alpha=20^\circ$ . Only the gear region that is in contact with the other gear in the mesh is

described by the involute shape. The root geometry or bottom land region, that connects two neighboring teeth, can be designed rather freely. Task completed in this paper, also done in ref. is to improve the gear strength by changing the gear geometry in a way that retains the involute shape. Bending stress plays a significant role in gear design where in its magnitude is controlled by the nominal bending stress and the stress concentration due to the geometrical shape. The bending stress is indirectly related to shape changes made to the cutting tool. Work shows that the bending stress can be reduced significantly by using asymmetric gear teeth and by shape optimizing the gear through changes made to the tool geometry. However, to obtain the largest possible stress reduction a custom tool must be designed depending on the number of teeth, but the stress reductions found are not very sensitive to small design changes. S.R. Kulkarni et al. Studied how affects the roots stress by changing the addendum modification. The addendum modification is called positive when the displacement is away from the gear center and it is considered as negative when in the direction towards the centre of the gear. Analysis done by both theoretical and analytical considered the addendum modification on root stress. Bending stress result was obtained from the universal testing machine with hydraulic type. Both results were validated. K.S. Manrulkar. Bending stress one of the failure mode of gear tooth. Backlash provided for avoid the jumping it can be provided by two method either increasing tooth thickness or reducing centre distance. Finite element analysis result compared with the theoretical value.

### 3. PROBLEM STATEMENT

From the literature survey, the problem statement of the current work is to carry out parametric analysis of the involutes spur gear tooth and to predict the effect of these parameters on bending strength. Gear parameter considered by industrial survey. Pressure angle  $\alpha=20^\circ$ , speed of pinion = 900 rpm, power= 15HP, Material grade EN8, Yield strength=465Mpa, Ultimate tensile strength=800MPa, Young's modulus= 205 Gpa, factor of safety=3.

### 4. METHODOLOGY

The design of experiments is consider one of the most comprehensive approaches in product developments. It is a statistical approach that attempts to provide a predictive knowledge of a complex, multi-variable process with few trials. Following is major approach to design of experiments.

#### 4.1 Taguchi method

Taguchi suggested a specially designed method called the use of the orthogonal array to study the entire parameter space with the lesser number of experiments to be conduct. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating

from the desired target value. This gives the nominal-smaller-the-better.

**Step 1:** Identification of main function and it's side effects. Main function- face width, module, no of teeth. Side effects- bending stress.

**Step 2:** Identifying the analysis condition. Analysis on ANSYS

**Step 3:** Identify the objective function. Smaller-the-better

**Step 4:** Identifying the control factors and their level-

**TABLE I: Selected factors and their level**

Factors	Level		
	1	2	3
Module	2.5	3	5
No of teeth	18	21	23
Face width	15	18	30

**Step 5:** Selection of orthogonal array- The most suitable orthogonal array for experimentation is L9

**TABLE III: Bending stress from lewis equation**

Exp No	Load	Module	No of teeth	Face width	Velocity factor	Lewis form factor	Bending stress
1	1500	2.5	18	15	0.7388	0.324	166.84
2	1500	2.5	21	18	0.7080	0.347	135.56
3	1500	2.5	23	30	0.6888	0.359	80.83
4	1500	3	18	30	0.7021	0.324	73.15
5	1500	3	21	15	0.6689	0.347	143.48
6	1500	3	23	18	0.6485	0.359	119.24
7	1500	5	18	18	0.5865	0.324	87.67
8	1500	5	21	30	0.5480	0.347	52.54
9	1500	5	23	15	0.5254	0.359	105.97

## 6. SIMULATION MODEL

Modelling of the spur gear is base on the design parameters. The material properties and parts assembly are also assign at this stage. This is followed by the FEA pre-processing stage where the mesh element, the load, and constraint is set on the involute spur gear model.

To determine the bending stress accurately, different mesh settings and FEA solver are require in separate setup. In the FEA post-processing stage, the FEA solution for the gear is complete. Thus, the bending stress analysis can be performe by correlating with the applied load and parameters.

**TABLE II: Orthogonal array**

Exp No	Control Factor		
	1	2	3
1	2.5	18	15
2	2.5	21	18
3	2.5	23	30
4	3	18	30
5	3	21	15
6	3	23	18
7	5	18	18
8	5	21	30
9	5	23	15

## 5. NUMERICAL MODEL

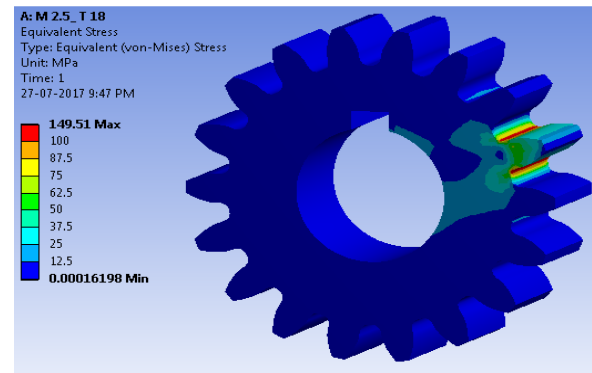
Bending Stress- Stresses developed by Normal force in a model of the gear tooth is called bending stress.

$$\text{Bending stress} = (F/bmy) * K_v$$

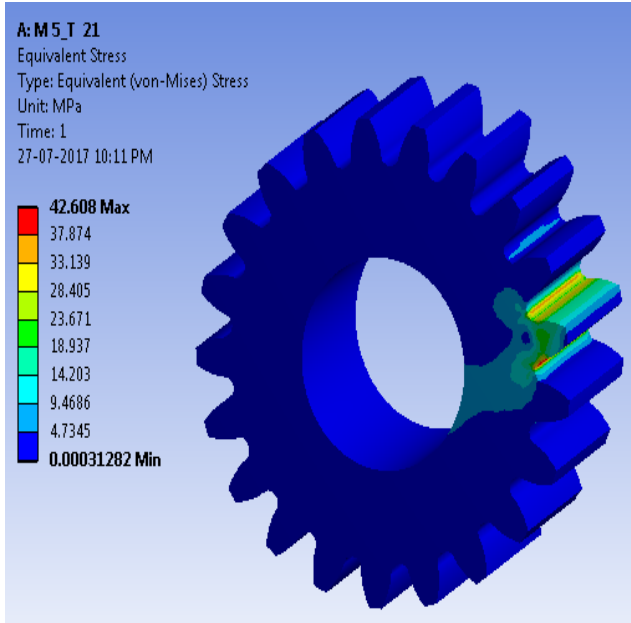
Where, F is tangential load,  $K_v$  is velocity factor, b is face width, m is module, Y is lewis form factor.

$$\text{Safe bending stress} = S_y/3$$

### 6.1 ANSYS Result



**Fig.1 Bending stress when face width is 15mm**



**Fig.2 Bending stress when face width is 30mm**

## 7. RESULT

In this work, the effect of a module, No of teeth and face width is consider for analysis. From the analysis, it is clear that, when the module, no of teeth and face width of the gear tooth are increase, the bending stress will be reduced by a certain amount. Experiment no.1 gives the maximum bending stress and experiment no.8 gives minimum bending stress. So, bending stress value of the experiment no.1 is above the allowable limit and for experiment no.8 is within the allowable limit. Bending stress value for experiment no.1 is  $166.84 \text{ N/mm}^2$  and for experiment no.8 is  $52.54 \text{ N/mm}^2$  by numerical method. Bending stress value for experiment no.1 is  $149.51 \text{ N/mm}^2$  and experiment no.8 is  $42.06 \text{ N/mm}^2$  by simulation method.

**TABLE IV: Optimum Values of factor and their values**

Parameter	Optimum value	Optimized value of bending stress ( $\text{N/mm}^2$ )
Module(mm)	5	
No of teeth	21	52.54
Face width(mm)	30	

## 8. CONCLUSION

Gear failure is the concern for power transmission. Exceeding the limiting values bending stress will result into pitting which leads to gear failure. In the present work, an attempt has been made to optimize the bending stress by modifying the parameters of the spur gear tooth. The effects of changing these parameters are discussed here. The effect of the module, number of teeth and face width is considering for analysis. From the analysis, it is observed, when the module, number of teeth and face width of the gear tooth are increase, the bending stress will be reduced by a certain amount. Using taguchi method with minimum iteration got the result. This stress reduction will lengthen the gear life.

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# Ranking the Enablers of Enterprise Resource Planning Implementation in Indian Industries Using Trapezoidal Fuzzy AHP Method

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**Abstract:** Many organizations that have implemented enterprise resource planning (ERP) systems unsuccessfully increase, it is necessary to establish the hindrance in ERP Implementations and the extent to which these impact the success of ERP projects. A group of experts from industries and academics was consulted. Fuzzy AHP method is used for decision making in effective ERP implementation with the help of Fuzzy concept. These methods established contextual relationship between different enablers and find out which enablers dominates on each other's for success of ERP implementation. The purpose of this paper is to identify the current literature base enablers for effective Enterprise Resource planning (ERP) Implementation and also this paper investigate the impact of magnitude of each enablers on the success performance of ERP implementation.

**Keywords:** Enterprise resource planning (ERP), ERP enablers (ERPEs), CSF, Fuzzy AHP

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## 1. INTRODUCTION

The implementation of ERP system poses challenges to organisations in terms of costs, process, planning, technology fit, and adoption (Das and Dayal, 2016). ERP system is a commercial software information system that integrates and unifies main business functions such as financial management, manufacturing, and human resource management in order to improve data consistency and incorporation of modular applications that support operational activities and business functions (Tian and Xu, 2015). The premeditated implications of ERP system to organisational performance are well documented (Sykes et al. 2014).

The adoption of (ERP) systems has been considered to be a key to gaining a competitive advantage in the fast changing global business environment. ERP system is a business management system that comprises integrated sets of comprehensive software that can be used, when successfully implemented, to manage and integrate all business processes and functions within an organization (Amini and Safavi, 2013). ERP system is widely implemented as the backbone of many manufacturing and service organizations (Kumar et al., 2003). ERP is central database that contains all of the transactions that an organization could implement, depending on its set of functional modules (Vathanophas et al., 2007). ERP system software based packages are highly integrated, complex systems for businesses (Koch, 1996). (Kumar et al., 2013) have defined ERP systems as configurable information systems packages that integrate information and information based processes within and across functional areas in an organization. ERP systems provide many

benefits to industries so they can meet changing expectations by providing accurate, timely, and integrated information to improve decision making (Trott and Hoecht, 2004). ERP is a tool that helps companies cut costs and improve efficiency by integrating business processes and sharing common resources across an organization (Zhang et al., 2002).

This paper proposes extended fuzzy AHP method based on the combination of the fuzzy AHP and trapezoidal fuzzy number for ranking the enablers of ERP Implementation in Indian Industries. In the proposed method, the weights of the enablers are derived from the fuzzy preference ratios (trapezoidal fuzzy number), thus the proposed method allows a more reasonable description of the decision making process and reflects the thinking style of human. However, for traditional fuzzy AHP, when calculating the weights of the indexes, although linguistic variables are adopted in the pairwise comparison, the exact values are used to represent the pairwise comparison and the results of the weights are usually presented with exact values, which cannot make full advantage of the fuzzy theory.

The rest of this paper is organized as follows. Section 2 briefly reviews the literature on enablers of ERP Implementation in Indian Industries. Section 3 presents the proposed method for ranking the enablers of ERP Implementation in Indian Industries. Empirical study is conducted and described in Section 4. Furthermore, discussion is described in section 5. Finally, conclusions are presented in Section 6.



## 2. LITERATURE REVIEW OF THE ENABLERS OF ERP IMPLEMENTATION IN INDIAN INDUSTRIES.

In order to adopt ERP effectively in Indian Industries. some creditable works have provided several enablers of ERP adoption in Indian Industries (see table I).

**TABLE I: Summary of literature review and experts Opinion**

Main Criteria	Criteria Code	Sub Criteria	References
Strategic Enabler (SE)	SE1	Top management	Sheng-Wei Lin (2016) Shaul and Tauber (2012), Kumar et al. (2014)
	SE2	Business plan and vision	Slavica Dožić et.al (2017) Law et al. (2007), Nickel (2010),
	SE3	ERP strategy	Lee et al.(2010), Nickel (2010)
	SE4	Linking strategy to execution	Al-Mashari and Al-Mudimigh (2003), Mabert et al. (2003)
	SE5	Consensus on execution and control	Kraemmerand et al. (2003), Sarker and Lee (2003)
Project Management Enabler (PME)	PME1	Clear vision and goals	Abbas Mardani et al.(2017), Ram et al.(2013),
	PME2	Process champion	Zhang et al. (2016), Lee et al.(2010)
	PME3	project management verdict	Michael F. Gorman et al.(2017), Finney and Corbett (2007)
	PME4	Support	chang et al.(2006), Doom (2010), Dezdard and Sulaiman (2011)
	PME5	Team composition and staffing	Law et al. (2007), Finney and Corbett (2007)
Organizational Enabler (OE)	OE1	Organizational culture	Ali TarhiniZhang et al. (2015)
	OE2	Team work	Haruna Jinno et al. (2016), Finney and Corbett (2007)
	OE3	Change management	İlkerGölcük et al. (2017), Umble (2003), Sarker and Lee (2003)
	OE4	Business Process Reengineering	chang et al. (2006), Doom et al. (2010), Dezdard and Sulaima (2011)
Process Management Enabler criteria (PMEC)	PMEC1	Customization	Somnath Roy et al. (2017), Dezdard and Sulaiman (2009),
	PMEC2	Standardization	Kraemmerand et al. (2003), Somers and Nelson (2004)
	PMEC3	Documentation	Sun et al. (2005), Zhang et al. (2005).
	PMEC4	Integration	Worley et al. (2005), Vathanophas (2007),
ERP Vendor Selection Enabler (EVSE)	EVSE1	Cost	Upadhyay (2008), Yang and Su (2009)
	EVSE2	User friendly	serker and Lee (2003), Somers and Nelson (2004), Zhang et al. (2005)
	EVSE3	Fitness	Somers and Nelson (2003), Kumar et al. (2003)
	EVSE4	Flexibility	Moon (2007), kumar et al. (2013)

Technology Management Enabler (TME)	EVSE5	ERP vendor support	kumar et al. (2013), Ram et al.(2013)
	TME1	Information technology	Somers and Nelson (2004), Zhang et al. (2005)
	TME2	Configuration	Krumbholz et al. (2001), Allen et al. (2002)
	TME3	Software selection	Law (2007), Ram et al.(2013)
	TME4	Data mitigation	Umble et al. (2003), Zhang (2003), Sun (2005),
	TME5	System monitoring	Gary B.Wills et al. (2016), Ehie and Madsen (2005)
People Characteristic Enabler (PCE)	TME6	Test and troubleshooting	Shaul and Tauber (2012), kumar et al. (2013), Ram et al.(2013)
	PCE1	Education and training	Dezdar and Sulaima (2015), Hasan (2011), kumar et al. (2013)
	PCE2	User involvement	chang et al. (2006), Doom (2010), Dezdar and Sulaima (2011)
	PCE3	Skills development	Christian Janiesch et al. (2017), Ram et al.(2013)
	PCE4	Knowledge management	Umble (2014), Zhang (2003), Sun et al. (2005), Zhang et al. (2005)
	PCE5	Communication	Doom et al. (2010), Dezdar and Sulaima (2011),

### 3. THE PROPOSED TRAPEZOIDAL FUZZY AHP METHOD TO RANK THE ENABLERS OF ERP IMPLEMENTATION IN INDIAN INDUSTRIES.

4. *The proposed trapezoidal fuzzy AHP for ranking the enablers of ERP Implementation In Indian Industries. has following two phases.*
5. *Identification of the Enablers of ERP Implementation In Indian Industries and Structure Decision Hierarchy*

**Step 1:** Establish Decision Group. A decision group of expert panel which comprising senior managers, IT representatives, ERP project representatives, senior executives of ERP members, and customers is formed.

**Step 2:** Identify the Criteria's and Creating Hierarchical Structure. In this step, the enablers of ERP Implementation in ERP are figured out based on the extensive literature review and discussion with decision group. Initially the decision problem decomposes into hierarchy with goal at top, major criteria and sub criteria at levels and sub levels. Then approve the decision hierarchy by discussing with the experts.

comparison matrix  $X$  is consistent, it means the fuzzy comparison matrix  $\tilde{X}$  is also consistent. The consistency can be checked as follows:

- i. Calculate largest Eigen value of the matrix by using Eq. vi

$$XW = \lambda_{\max} W \quad (vi)$$

Where  $w$  is principal Eigen vector of the matrix.

- ii. The Consistency Ratio (CR) is used to estimate directly the consistency of pairwise comparisons. The CR is computed by using Eq. vii

$$CR = \frac{CI}{RI} \quad (vii)$$

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (viii)$$

Where, CI is consistency index.

RI is random index, which is shown in table III,  $n$  is matrix size.

**TABLE II: The random consistency index (RI)**

Size (n)	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

As a rule, only if the  $CR \leq 0.10$ , the consistency of the matrix is considered as acceptable, otherwise the decision maker is required to revise the original values in the pairwise comparison matrix

**Step 5:** Calculate the Weight of Criteria's. The Criteria weights can be calculated based on the Normalized pairwise comparison matrix X by using the following steps

The Criteria weights can be calculated based on the Normalized pairwise comparison matrix X by using the following steps

- First calculate sum of all the elements in each column.
- Then divide every element of each column by their respective sum of all elements.
- After that determine the sum of all the elements in each row of the matrix and divide the sum of all elements for each row by the order of matrix and get the weight of corresponding criteria.

Step 6: Prioritize the Criteria's. The Final weight of each criterion can be obtained by multiplying the ratio weight of sub criteria by major criteria's weight. According to final weight prioritize the criteria.

#### 4. EMPIRICAL STUDY

In this section, an empirical study is presented to illustrate the application of the proposed trapezoidal fuzzy AHP method for identifying and ranking the enablers of ERP Implementation In Indian Industries.

##### 4.1 Problem Description

To achieve competitive advantage Endurance technologies manufacturing organization located in India interested to identify and rank the enablers of ERP Implementation in

Indian Industries. The organization has about 5000 employees, 85 suppliers and vendors and turn over about 1000 corers. The proposed method applied in this case organization

##### 4.2 Application of the Proposed Trapezoidal Fuzzy AHP Method to Rank the Enablers of ERP Implementation in Indian Industries

In the first phase, the decision group is composed of the 10 expert panel which comprising three senior managers, two IT representatives, three senior executives of ERP members, and three customers. In this study 34 enablers (sub-criteria) of ERP Implementation in Indian Industries are identified through literature review and intensive discussion with decision group members (see Table I). These sub criteria divided into seven main criteria. There are four levels in the decision hierarchy structure for this problem. The overall goal of decision process determined as "ranking the enablers of ERP Implentation in Indian Industries" is in the first level of hierarchy, the main criteria for the second level and the sub criteria at the third level of hierarchy (see Table I). Then this decision hierarchy is approved by an expert panel.

In the second phase decision group is asked to make pairwise comparisons of seven main criteria and 34 sub criteria (enablers) by using linguistic variables by using table II. The arithmetic means of these values are computed to obtain the pairwise comparison matrixes of criteria and sub-criteria are given in Table III-X.

The results obtained from the calculations based on pairwise comparison matrixes provided in Table 3 to 10 and following the procedure given in the previous section, are presented in Table 11. CR values of all the matrixes are less than 0.1, Hence, these matrixes are consistent.

**TABLE III: The pairwise comparison of major criteria**

Attributes	Strategic Enabler (SE)	Project Management Enabler (PME)	Organizational Enabler (OE)	Process Management Enabler criteria (PMEC)	ERP Vendor Selection Enabler (EVSE)	Technology Management Enabler (TME)	People Characteristic Enabler (PCE)
Strategic Enabler (SE)	1	3	3	5	7	5	7
Project Management Enabler (PME)	$3^{-1}$	1	5	5	5	3	3
Organizational Enabler (OE)	$3^{-1}$	$5^{-1}$	1	3	3	5	3
Process Management Enabler	$5^{-1}$	$5^{-1}$	$3^{-1}$	1	1	1	1

Attributes	Strategic Enabler (SE)	Project Management Enabler (PME)	Organizational Enabler (OE)	Process Management Enabler criteria (PMEC)	ERP Vendor Selection Enabler (EVSE)	Technology Management Enabler (TME)	People Characteristic Enabler (PCE)
criteria (PMEC)							
ERP Vendor Selection Enabler (EVSE)	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	1	$\tilde{1}$	$\tilde{1}$
Technology Management Enabler (TME)	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	1	$\tilde{1}$
People Characteristic Enabler (PCE)	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	1

**TABLE IV: The pairwise comparison of Strategic Enabler (SEs)**

	SE1	SE2	SE3	SE4	SE5
SE1	1	$\tilde{5}$	$\tilde{7}$	$\tilde{7}$	$\tilde{5}$
SE2	$\tilde{5}^{-1}$	1	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
SE3	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{1}$
SE4	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}$
SE5	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	1

**Table V: The pairwise comparison of Project Management Enabler (PMEs)**

	PME1	PME2	PME3	PME4	PME5
PME1	1	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$
PME2	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$
PME3	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{3}$
PME4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}$
PME5	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	1

**TABLE VI: The Pairwise Comparison of Organizational Enabler (OEs)**

	OE1	OE2	OE3	OE4
OE1	1	$\tilde{5}$	$\tilde{5}$	$\tilde{5}$
OE2	$\tilde{5}^{-1}$	1	$\tilde{3}$	$\tilde{3}$
OE3	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}$
OE4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	1

**TABLE VII: The Pairwise Comparison of Process Management Enabler Criteria (PMECs)**

	PMEC1	PMEC2	PMEC3	PMEC4
PMEC1	1	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$
PMEC2	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{3}$
PMEC3	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}$
PMEC4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	1

**TABLE VIII: The pairwise comparison of ERP Vendor Selection Enabler (EVSEs)**

	EVSE1	EVSE2	EVSE3	EVSE4
EVSE1	1	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$
EVSE2	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{3}$
EVSE3	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}$
EVSE4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1

**TABLE IX: The pairwise comparison of Technology Management Enabler (TMEs)**

	TME1	TME2	TME3	TME4
TME1	1	$\tilde{3}$	$\tilde{5}$	$\tilde{7}$
TME2	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{5}$
TME3	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{5}$
TME4	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	1
TME5	$\tilde{9}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
TME6	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$

**TABLE X: The pairwise comparison of People Characteristic Enabler (PCEs)**

	PCE1	PCE2	PCE3	PCE4	PCE5
PCE1	1	$\tilde{3}$	$\tilde{3}$	$\tilde{7}$	$\tilde{5}$
PCE2	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{5}$	$\tilde{3}$
PCE3	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}$	$\tilde{1}$
PCE4	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}^{-1}$	1	$\tilde{1}$
PCE5	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	1

## 5. DISCUSSION

Through extensive literature review and discussion with decision group total 34 enablers of ERP Implementation in Indian Industries are identified. These enablers are grouped in to seven major criteria's as Strategic Enabler, Project Management Enabler, Organizational Enabler, Process Management Enabler criteria, ERP Vendor Selection Enabler, Technology Management Enabler, People Characteristic Enabler. It observed from Table XI shows that ranking of weights for ERPEs strategic ERPEs are found be highest of importance among all with the weight of 0.2116 followed by the Project Management ERPEs with weight of 0.1093. After these two, ERPEs namely organizational and Process Management are ranked lower down the order in the ranking of importance with the weights 0.0939 and 0.0285 respectively. The result of empirical study shows strategic ERPEs is the highest rank, Project Management ERPEs is second and organizational management among the all ERP Enablers. The organization should concentrate on these high rank enablers on priority basis and remaining on stepwise manner for effective ERP Implementation in Indian Industries.

## 6. CONCLUSION

To adapt to today's challenging and competitive business environment, organizations are implementing ERP systems to achieve a capability to plan and integrate enterprise wide resources in order to shorten lead times, and to be more responsive to customer demands. Throughout the literature review, 34 ERPEs related to implementation of ERP systems were identified. These ERPEs have been ranked according to their final score based on importance weight of each ERPE obtained by FAHP methodology (Table 11). According to ranking of weights for ERPEs strategic enablers are found be highest of importance among all with the weight followed by the Project Management enablers. Further according to the (Table 12) of priority of weights, it can be observed that the strategic enabler (SE1) which is Top management holds the first rank among them with that an enablers from Project Management enablers category, Clear vision and goals for the ERP (PME1) ranked at number two. Major driving force for Successful implementation of ERP involved the top management support and this enabler setting the strategic direction of the implementation process. This enabler correlates the highest with ERP implementation among all the enablers identified in the study. This is accomplished by a continuous support and monitoring of the implementation process. The results of this study can be used in future to develop evidence based on ranking order of the ERPEs. The ERPEs have been generalized and may be poor in quality or very specific for some organizations but this study may found to be helpful for organization management to come at critical enablers for their ERP Implementation. Further some more criteria ERPEs can be considered and taken into account for modelling.

**TABLE XI: Final Priority of ERPEs Implementation in Indian industries**

Major Enabler Name	Major criteria weight	C. code	CR	Ratio weight	Final weight	Rank
Strategic Enabler	0.3787	SE1	0.0588	0.5587	0.2116	1
		SE2		0.1971	0.0746	4
		SE3		0.1029	0.0390	7
		SE4		0.0655	0.0248	12
		SE5		0.0756	0.0286	9
Project Management Enabler	0.2508	PME1	0.0703	0.4358	0.1093	2
		PME2		0.2660	0.0667	5
		PME3		0.1626	0.0408	6
		PME4		0.0731	0.0183	15
		PME5		0.0624	0.0157	16
Organizational Enabler	0.1585	OE1	0.0648	0.5922	0.0939	3
		OE2		0.2210	0.0350	8

		OE3		0.0966	0.0153	18
		OE4		0.0902	0.0143	19
Process Management Enabler criteria	0.0562	PMEC1	0.057	0.5073	0.0285	10
		PMEC2		0.2722	0.0153	17
		PMEC3		0.1248	0.0070	24
		PMEC4		0.0955	0.0054	27
ERP Vendor Selection Enabler	0.0504	EVSE1	0.0489	0.4948	0.0249	11
		EVSE2		0.2520	0.0127	22
		EVSE3		0.1167	0.0059	25
		EVSE4		0.0731	0.0037	29
		EVSE5		0.0634	0.0032	32
Technology Management Enabler	0.0542	TME1	0.0717	0.4470	0.0242	13
		TME2		0.2480	0.0135	21
		TME3		0.1439	0.0078	23
		TME4		0.0644	0.0035	31
		TME5		0.0437	0.0024	34
		TME6		0.0529	0.0029	33
People Characteristic Enabler	0.0508	PCE1	0.0245	0.4724	0.0240	14
		PCE2		0.2689	0.0136	20
		PCE3		0.1060	0.0054	26
		PCE4		0.0716	0.0036	30
		PCE5		0.0809	0.0041	28

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# Genetic Algorithm Based Hybrid Approach to Solve Multi-Objective Interval Assignment Problem

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**Abstract:** The present paper proposed Genetic Algorithm (GA) based hybrid approach to solve multi-objective interval assignment problem (MOIAP) using a risk attitude parameter. Few researchers have been developed an approach for finding the solution of MOIAP but they used the traditional method like weighted min-max method, fuzzy method etc. Our experiment with 4-persons and 4-jobs of MOIAP, show that GA based hybrid approach gives better analysis rather than other developed approaches as DM is required to specify the different aspiration level as per his/her preference to obtain an efficient assignment plan with different shape parameter in the exponential membership function. Moreover, in this paper we have also discussed the sensitive analysis of decision parameters of MOIAP. A numerical example is provided to demonstrate the effectiveness of the proposed approach with data set from the realistic situation. This research concludes that developed hybrid approach in this work is provided analysis based effective output to take decision rather than another approach.

**Keyword:** Assignment problem, Interval parameters, Risk attitude parameter, Genetic algorithm

## 1. INTRODUCTION

An assignment problem is well-known in which objective is to assign a number of jobs to an equal number of machine/ persons/ facilities with optimum decision parameters. The mathematical formulation of the problem suggests that this is a 0-1 linear programming problem and is highly degenerate. However, in real life situations, the elements of the effective matrices of assignment problem should be imprecise number instead of deterministic number as decision parameters for one job is assigned to one person might vary due to people's limited knowledge related to the problematic areas, the lack of data, inaccurate estimation etc. The inaccurate information of decision parameter may be in the type of interval numbers [Kai et al., 2011]. Thus, these axes of evaluation are normally operationalized by objective functions to be optimized in the structure of Interval Assignment Problem (IAP) model. When, assignment problem with interval numbers involve multiple decision variables, in this situation IAP form a new problem as multi-objective interval assignment problem (MOIAP). Thus, new methods for solving the multi-objective assignment problem with interval numbers are needed.

To find the solution of multi-objective interval assignment problem (MOIAP), several methods which are available for multi-objective interval linear programming problem can be utilized. In particular, there are few studies on multi-objective interval assignment problem available in the literature. To the best of our knowledge, Kagade K. L. et al., 2010 have obtained the solution of multi-objective assignment problem with interval cost using fuzzy method. Shen kai et al. [Kai et al., 2011] proposed a solution method for solving the MOIAP using risk attitude parameter (RAP).

Salehi, K. (2014) has developed an approach for solving MOAP with interval parameter using the substitution variables approach. In addition, to transform the multi-objective problem into a single objective optimization problem, a weighted min-max method is applied. Tailor and Dhodiya, 2016 have developed a genetic algorithm based hybrid approach to solve multi-objective interval assignment problem with using estimation theory.

## 2. MATHEMATICAL FORMULATION OF MULTI-OBJECTIVE INTERVAL ASSIGNMENT PROBLEM:

The general mathematical formulation of multi-objective interval assignment problem is as follows [Kagade K. L. et al., 2010; Kai et al., 2011; Salehi, K. (2014; Tailor and Dhodiya, 2016 ]:

**Model-1:**

$$\min Z_k = \sum_{i=1}^n \sum_{j=1}^n [Z_{ijk}^L, Z_{ijk}^U] x_{ij}; k = 1, 2, \dots, m$$

Subject to:

$$\sum_{j=1}^n x_{ij} = 1; i = 1, 2, \dots, n \quad (I)$$

$$\sum_{i=1}^n x_{ij} = 1; j = 1, 2, \dots, n \quad (II)$$

$$x_{ij} = \begin{cases} 1; & \text{if } i^{\text{th}} \text{ job is assigned to } j^{\text{th}} \text{ machine} \\ 0; & \text{if } i^{\text{th}} \text{ job is not assigned to } j^{\text{th}} \text{ machine} \end{cases} \quad (III)$$



where  $[Z_{ijk}^L, Z_{ijk}^U]$  is an interval representing the uncertain parameter for the assignment problem. Here  $(Z_{ij1}^L, Z_{ij2}^L, \dots, Z_{ijk}^L)$  and  $(Z_{ij1}^R, Z_{ij2}^R, \dots, Z_{ijk}^R)$  represent left bound and right bound for  $Z_k$  respectively.

This paper deals with an alternative approach is to find the solution of special case of multi-objective optimization problem with interval number as multi-objective interval assignment problem (MOIAP). To find the solution of MOIAP, we used Genetic algorithm (GA) based approach with risk attitude parameter as GA based hybrid approach provided an efficient solution as well as other alternative solutions nearer to optimal solutions in uncertain situation based problem. These alternative solutions play some significant role to take the decision to DM. Paper also discussed its sensitivity analysis regarding risk attitude parameter for each objective.

### 3. GA BASED HYBRID APPROACH TO SOLVE MOIAP USING RISK ATTITUDE PARAMETER:

For assignment analysis process/ to manage the uncertainty in MOIAP, DM is introduced the different parameters/approach like as risk attitude parameter, order relations between interval, fuzzy technique, substitution variable approach, Interval estimation etc. Out of them, risk attitude parameter is used to convert the interval numbers into crisp values and the sensitivity analysis can also be conducted by change the values of risk attitude parameter.

#### 3.1 Preliminaries:

##### Interval Arithmetic:

For basic concepts and operation of interval  $\tilde{x} = [x^L, x^U] = \{x / x^L \leq x \leq x^U, x \in R\}$ , where  $x^L$  and  $x^U$  denoted as lower limit and upper limit respectively,  $R$  is the set of real numbers, researcher refer [4] which play significant role for the analysis of multi-objective interval assignment problem.

##### Risk attitude parameter:

For positive interval number  $\tilde{x} = [x^L, x^U]$ , the interval mapping function is defined as follows [4]:

$$\phi_\varepsilon(x) = m(\tilde{x}) + (\varepsilon)d(\tilde{x}); \quad (IV)$$

where  $\varepsilon$  is Decision maker's (DM) risk attitude parameter for uncertain data of real world problem and it is  $|\varepsilon| \leq 0.5$

$$m(\tilde{x}) = \frac{x^U + x^L}{2} \text{ is the center of } \tilde{x},$$

$$d(\tilde{x}) = x^U - x^L \text{ is the difference of an interval } \tilde{x}.$$

For Assignment analysis process, the DM gives risk attitude parameter. The risk attitude parameter can be divided into optimistic, most likely and pessimistic and the corresponding values for  $\varepsilon$  are  $-0.5 \leq \varepsilon < 0, \varepsilon = 0, 0 < \varepsilon \leq 0.5$  respectively. Once risk attitude parameter can be determined then interval value converts in crisp values by equation (IV).

#### 3.2 Formulation of crisp multi-objective optimization model using risk attitude parameter:

To convert the model-1 into crisp multi-objective optimization model, the risk attitude parameter is used as follows:

Let  $Z_k = [z_{ijk}]_{n \times n}$  is the cost (profit and loss) matrix with respect to the objective  $k$ , where  $z_{ijk} = [z_{ijk}^L, z_{ijk}^U]$  is representing the cost if person  $A_i$  assigned jobs  $B_j$  with respect to the objective  $k$ ; where  $i, j = 1, 2, \dots, n, k = 1, 2, \dots, m$ . Here,  $Z_k = [z_{ijk}]_{n \times n}$  is the profit and loss matrix with interval numbers, is converted into crisp values  $Z_k^\varepsilon = [z_{ijk}^\varepsilon]_{n \times n}$  by using the equation

$$Z_k^\varepsilon = [z_{ijk}^\varepsilon] = \frac{(z_{ijk}^U + z_{ijk}^L)}{2} + \varepsilon(z_{ijk}^U - z_{ijk}^L), \quad i, j = 1, 2, \dots, n, \quad k = 1, 2, \dots, m \quad (V)$$

#### 3.3 Crisp multi-objective optimization model:

To reflect the different scenario using risk attitude parameter, the multi-objective interval assignment problem is converted into crisp multi-objective optimization problem can be written as follows:

Model-2:

$$\min Z_k^\varepsilon = \sum_{i=1}^n \sum_{j=1}^n [z_{ijk}^\varepsilon]$$

Subject to:

Constraints (I) - (III)

### 4. SOLUTION APPROACH FOR SOLVING CRISP MULTI-OBJECTIVE OPTIMIZATION MODELS OF MOIAP WITH RISK ATTITUDE PARAMETER

To characterize the indistinct aspiration level of the DM, fuzzy membership functions like linear, piecewise linear, exponential, tangent etc are used. Out of them linear membership functions is most used because it is defined by two fixing points: upper bound and lower bound of the objective but some complexity are created when linear membership function is used see [29]. Additionally, membership function is used for describing the behavior of uncertain values, utilization of fuzzy data; preference, etc. In such situation, nonlinear membership function is offered healthy representation than others as to reflect the reality as

the marginal rate of increase of membership values as a function of model parameter is not constant [Dhodiya JM, Tailor, 2016; Gupta et al., 2013; Tailor and Dhodiya, 2016].

For solving the non-linear, discrete, non-convex types of large scale optimization problem, GA provided a proper output. Genetic algorithm is a most adaptive optimization search methodologies based on machine of natural genetics, natural selection and survival of fitness in biological system. It is work by mimicking the evaluating principle and chromosome processing in natural genetics [Dhodiya and Tailor (2016), Gupta et al., 2013, Koza, 1992, Ratli, 2013, 8-10]. For find the solution of MOIAP by GA, first encode chromosomes according to problem and define fitness function to measure the chromosomes. Thereafter apply three operators, selection, crossover and mutation to generate the new population. Selection process is forming a parent population for creating the next generation. Crossover process is the process of selecting two parents of chromosomes and produces a new offspring chromosome. Mutation process is process with mutation rate randomly alter selected positions in a selected chromosome. Thus the new population is generated by replacing some chromosomes in the parent population with the children population which is useful for find efficient solution.

This section present GA based hybrid approach for MOIAP to determine the best efficient solution with different aspiration levels given by DM.

**Algorithm:**

**Input:** Parameters:  $(Z_1, Z_2, \dots, Z_m, n)$

**Output:** Solution of MOIAP

Solve MOIAP ( $Z_k \downarrow, X \uparrow$ )

**begin**

read: example

**while** example = MOAIP **do**

for  $k=1$  to  $m$  **do**

enter matrix  $Z_k$

**end**

-| **define the crisp multi-objective optimization problem according to risk attitude parameter.**

-| **Convert the maximization problem into minimization problem.**

-| **determine the positive ideal solution and negative ideal solution for each objective.**

for  $k=1$  to  $m$  **do**

$Z_k^{PIS} = \min Z_k^e$

Under given constraints (I)- (III)

**end**

for  $k=1$  to  $m$  **do**

$Z_k^{NIS} = \max Z_k^e$

Under given constraints (I)- (III)

**end**

-| **Define an exponential membership function for each objective.**

for  $k=1$  to  $m$  **do**

$$\mu_{z_{ij}}^E(x) = \begin{cases} 1; & \text{if } z_{ij} \leq z_{ij}^{PIS} \\ \frac{e^{-S\psi_{ij}(x)} - e^{-S}}{1 - e^{-S}}, & \text{if } z_{ij}^{NIS} < z_{ij} < z_{ij}^{PIS} \\ 0; & \text{if } z_{ij} \geq z_{ij}^{NIS} \end{cases}$$

**end**

-| **find single objective optimization models under given constraints from multi-objective optimization model.**

for  $k=1$  to  $m$  **do**

$\max W = \prod_{k=1}^m \mu_{z_k}^E$

Subject to:

Constraints (I) - (III)

$\mu_{z_k^e}(x) - \overline{\mu_{z_k^e}}(x) \geq 0; k = 1, 2, \dots, m$

**end**

-| **find the solution of sop using GA**

**Procedure:** GA

**Begin**

Generation=0;

P= Generate the initial population of solution.

**For** ( $X \in P$ )

Evaluate  $W(X)$ ; ( $W(X)$  is objective function of X.)

**end**

**While** (Stopping criterion not met)

{Generation=Generation+1;

**Begin**

-| Apply tournament selection;

**For**  $P' \in P$

$P'$ =select fitness individual from P for matting pool according to tournament selection.

$P'' = \phi$

**end**

Repeat (Until enough children produced)

**For**  $P_1, P_2 \in P'$

*Select  $P_1$  and  $P_2$  from  $P'$ .*  
*Apply the partially matched crossover*  
*on  $P_1$  and  $P_2$  for produced new*  
*offspring.*  
 $P'' = P'' \cup X \text{ child ;}$   
**end**  
  
*Repeat*  
**For**  $X \in P''$   
*Make a threshold, to keep the best*  
*individuals.*  
**end**  
  
*For*  $X \in P''$   
*Apply inversion on  $X$ .*  
**end (begin)**  
 $P = P''$ ;  
**end (while)**  
**end (begin)**  
**end**

## 5. NUMERICAL EXAMPLES AND RESULT ANALYSIS

To justify proposed method, the multi-objective interval assignment problem has been refereed from the article Shen Kai et al, [Kai et al., 2011] which shown in Table-I. Let us consider the assignment problem of the matches between developing teams and development tasks of new product. In the problem, there are four developing teams ( $M_1, M_2, M_3, M_4$ ) and four new products ( $N_1, N_2, N_3, N_4$ ) which are needed to be developed. In the assignment analysis process, there are three objectives need to be considered: Development period ( $Z_1$ ): The grater the development period is, the more resources of company are occupied, Fund Investment ( $Z_2$ ): The development of a new product will consume huge fund, Expected effect ( $Z_3$ ): Whether the new product can meet the customers' demand well or not is important in the product development. Excepted effect of development is benefit type objectives whose value is in the form of interval number between 0 and 1.

**TABLE I: profit and loss matrices under each objective**

		$M_1$	$M_2$	$M_3$	$M_4$
$Z_1$	$N_1$	[120,140]	[110,150]	[100,160]	[105,160]
	$N_2$	[60,100]	[65,95]	[70,90]	[65,90]
	$N_3$	[180,220]	[190,210]	[160,240]	[170,230]
	$N_4$	[60,80]	[60,80]	[50,90]	[65,75]
$Z_2$	$N_1$	[20,25]	[19,27]	[18,27]	[21,24]
	$N_2$	[11,13]	[9,12]	[10,12]	[9,11]
	$N_3$	[25,23]	[26,30]	[27,31]	[27,30]
	$N_4$	[5,9]	[6,7]	[4,8]	[4,9]
$Z_3$	$N_1$	[0.7,0.9]	[0.8,0.9]	[0.7,1]	[0.6,1]
	$N_2$	[0.8,0.9]	[0.7,0.9]	[0.8,1]	[0.6,1]
	$N_3$	[0.6,0.8]	[0.6,1]	[0.8,0.9]	[0.6,0.9]
	$N_4$	[0.7,0.9]	[0.7,0.8]	[0.7,1]	[0.7,1]

The following settings of the parameters are used to solve different problem instances: number of tasks (n) = number of workers (n) = 4, number of objective = 3.

Table-II gives the PIS and NIS for each objective function of model-2 at different risk attitude parameters  $\varepsilon = -0.5$ ,  $\varepsilon = 0$  and  $\varepsilon = 0.5$ . These values are used in the exponential

membership function of each objective. For the uniformity, we convert maximize quality function into minimize function and then find the solution.

Efficient solutions of MOIAP are reported in the Table- III for different values of risk attitude parameter  $\varepsilon = -0.5$ ,  $\varepsilon = 0$  and  $\varepsilon = 0.5$  which are given by DM.

**TABLE-II: PIS and NIS for each objective function at  $\varepsilon = -0.5$ ,  $\varepsilon = 0$  and  $\varepsilon = 0.5$**

$\alpha$ – level	Solutions	Objectives		
		$Z_1$	$Z_2$	$Z_3$
$\varepsilon = -0.5$	PIS	385	56	0.1
	NIS	445	65	0.6
$\varepsilon = 0$	PIS	477.5	66.5	0.2
	NIS	482.5	70.5	0.5
$\varepsilon = 0.5$	PIS	515	74	0.1
	NIS	580	80	0.4

According to risk attitude parameters, the assignment plans for multi-objective interval assignment problems are reported in Table-IV with different values of the shape parameters and aspiration levels which specified by the DM.

Each combination of the shape parameters and its corresponding different aspiration levels are shown in Table-III.

**TABLE-III: Different values of shape parameters and aspiration level**

Case	Shape parameter ( $K_1, K_2, K_3$ )	Aspiration level ( $\bar{\mu}_{Z_{1j}}(x), \bar{\mu}_{Z_{2j}}(x), \bar{\mu}_{Z_{3j}}(x)$ )
Case-1:	(-5, -5, -5)	0.9, 0.85, 0.7
Case-2:	(-3, -3, -3)	0.8, 0.7, 0.85
Case-3:	(-2, -2, -2)	0.7, 0.65, 0.75
Case-4:	(-1, -1, -1)	0.6, 0.5, 0.7

**TABLE-IV: Summary results at  $\varepsilon = -0.5$ ,  $\varepsilon = 0$  and  $\varepsilon = 0.5$**

$\alpha$	Case	Degree of satisfaction	Membership values ( $\mu_{Z_{1j}}, \mu_{Z_{2j}}, \mu_{Z_{3j}}$ )	Objective values $Z_1, Z_2, Z_3$	Optimum allocations:
$\varepsilon = -0.5$	1	0.9442	(0.9912, 0.9442, 0.9567)	(395, 60, 2.9)	$M_1 \rightarrow N_2, M_2 \rightarrow N_4, M_3 \rightarrow N_3, M_4 \rightarrow N_1$
	2	0.7750	(0.9660, 0.7750, 1.0000)	(395, 61, 3.1)	$M_1 \rightarrow N_2, M_2 \rightarrow N_1, M_3 \rightarrow N_3, M_4 \rightarrow N_4$
	3	0.6811	(0.9381, 0.6811, 1.0000)	(395, 61, 3.1)	$M_1 \rightarrow N_2, M_2 \rightarrow N_1, M_3 \rightarrow N_3, M_4 \rightarrow N_4$
	4	0.5676	(0.8945, 0.5676, 1.0000)	(395, 61, 3.1)	$M_1 \rightarrow N_2, M_2 \rightarrow N_1, M_3 \rightarrow N_3, M_4 \rightarrow N_4$
$\varepsilon = 0$	1	0.9241	(1.0000, 1.0000, 0.9241)	(477.5, 66.5, 3.25)	$M_1 \rightarrow N_1, M_2 \rightarrow N_4, M_3 \rightarrow N_2, M_4 \rightarrow N_3$
	2	0.8176	(0.8176, 0.8910, 0.9660)	(480, 68, 3.35)	$M_1 \rightarrow N_1, M_2 \rightarrow N_3, M_3 \rightarrow N_2, M_4 \rightarrow N_4$
	3	0.7311	(0.7311, 0.8252, 0.9381)	(480, 68, 3.35)	$M_1 \rightarrow N_1, M_2 \rightarrow N_3, M_3 \rightarrow N_2, M_4 \rightarrow N_4$
	4	0.6225	(0.6225, 0.7325, 0.8945)	(480, 68, 3.35)	$M_1 \rightarrow N_1, M_2 \rightarrow N_3, M_3 \rightarrow N_2, M_4 \rightarrow N_4$
$\varepsilon = 0.5$	1	0.9853	(0.9853, 1.0000, 1.0000)	(530, 74, 3.9)	$M_1 \rightarrow N_1, M_2 \rightarrow N_4, M_3 \rightarrow N_2, M_4 \rightarrow N_3$
	2	0.9477	(0.9477, 1.0000, 1.0000)	(530, 74, 3.9)	$M_1 \rightarrow N_1, M_2 \rightarrow N_4, M_3 \rightarrow N_2, M_4 \rightarrow N_3$
	3	0.9082	(0.9082, 1.0000, 1.0000)	(530, 74, 3.9)	$M_1 \rightarrow N_1, M_2 \rightarrow N_4, M_3 \rightarrow N_2, M_4 \rightarrow N_3$
	4	0.9853	(0.9853, 1.0000, 1.0000)	(530, 74, 3.9)	$M_1 \rightarrow N_1, M_2 \rightarrow N_4, M_3 \rightarrow N_2, M_4 \rightarrow N_3$

According to different values of shape parameter and different estimates of aspiration levels, Table-IV shows the assignment plans for each objective at different values of risk attitude parameters  $\varepsilon = -0.5$ ,  $\varepsilon = 0$  and  $\varepsilon = 0.5$ .

### 5.1 Convergence criteria:

To find the convergence criteria of GA for  $(-5, -5, -5)$  shape parameter and  $(0.9, 0.85, 0.7)$  aspiration level at different risk attitude parameters  $\varepsilon = -0.5$ ,  $\varepsilon = 0$  and  $\varepsilon = 0.5$ , we have used different population and different iterations in the cases of using mutation operator and without using mutation operator

The developed algorithm converges after 40 populations and 60 iterations as well as 20 populations and 20 iterations in cases of without mutation operator and with the mutation operator at  $\varepsilon = -0.5$  for  $(-5, -5, -5)$  shape parameter and  $(0.9, 0.85, 0.7)$  aspiration level respectively. Similarly, the developed algorithm converges after 30 populations, 20 iterations and 70 populations, 100 iterations in case of without mutation operator as well as 10 populations, 10 iterations and 40 populations, 60 iterations in case of with the mutation operator at  $\varepsilon = 0$  and  $\varepsilon = 0.5$ . for  $(-5, -5, -5)$  shape parameter and  $(0.9, 0.85, 0.7)$  aspiration level respectively. Its also provided alternative choices of the solutions to DM as per his/her necessity. For other shape parameter and aspiration level, the convergence criteria of GA approximately remain same.

### 5.2 Sensitivity analysis:

Sensitivity analysis is used here to enlighten the effect of uncertainty in DM's judgment.

#### Sensitivity analysis with respect to $\varepsilon$ for different shape parameters and its corresponding aspiration levels

For multi-objective interval assignment problem, the sensitivity analysis of assignment plans at the different values of risk attitude parameters  $\varepsilon$  for  $(-5, -5, -5)$  shape parameter and  $(0.9, 0.85, 0.7)$  aspiration level is discussed in Figure-1.

In order to observe the sensitivity analysis of risk attitude parameter, normalized values of  $z_1^\varepsilon, z_2^\varepsilon, \& z_3^\varepsilon$  are required. Hence, in this case, normalized values are obtained by dividing all the objective function by its maximum number and sensitivity of the solution with respect to  $\varepsilon$  is described in Figure-1.

In the Figure-1, when ' $\varepsilon$ ' moves from left side to the average value of the interval, values of  $Z_1, Z_2$  and  $Z_3$  are increase. When  $\varepsilon$  moves from 0 to 0.1, value of  $Z_2$  is decrease and  $Z_1$  and  $Z_3$  increases while ' $\varepsilon$ ' moves from

0.1 to 0.5, values of  $Z_1, Z_2$  and  $Z_3$  increases Figure-1 shows the nature of objective functions of MOIAP under different values of risk attitude parameter. Figure-1 also indicate that, values of  $\varepsilon$  between "-0.1 to 0"; value of  $Z_2$  decrease which provided an opportunity to take decision for find the better alternatives to DM.

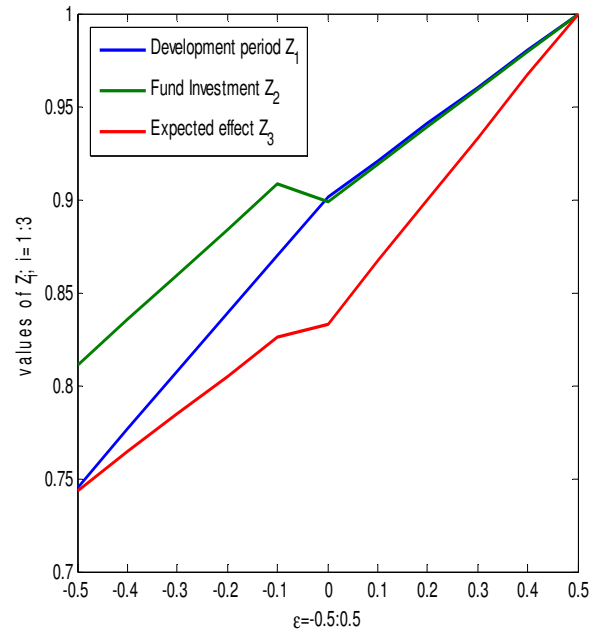


Fig.-1.

#### Sensitivity of different values of $\varepsilon$ and corresponding solutions at $(-5, -5, -5)$ shape parameter and $(0.9, 0.85, 0.7)$ aspiration level.

Similarly, we can show that the sensitivity analysis for the different values of risk attitude parameters for the different shape parameters and different aspiration levels.

Similarly, we can also shows the sensitivity analysis with respect to the different values of  $\varepsilon$  for each objective at  $(-5, -5, -5)$  shape parameters and  $(0.9, 0.85, 0.7)$  aspiration level as well as different shape parameters and different aspiration level.

## 6. COMPARISON BETWEEN DEVELOPED HYBRID APPROACH AND SHEN KAI'S APPROACH:

When the different weights are given by the DM to each objective then efficient assignment is obtained which is described in Table-V. Table-V also shows the comparisons between the developed hybrid approach and Kai et al. (2011) approach.

**TABLE-V: Comparison of results obtained by different approach for MOIAP**

$-\epsilon$	Shen Kai et al approach [4]	Shape parameter	Aspiration level	GA based hybrid approach with $\epsilon$
-0.5	$Z_1 = 395$ $Z_2 = 61$ $Z_3 = 3.1$	(-5, -5, -5)	0.9, 0.85, 0.7	(395, 60, 2.9)
		(-3, -3, -3)	0.8, 0.7, 0.85	(395, 61, 3.1)
		(-2, -2, -2)	0.7, 0.65, 0.75	(395, 61, 3.1)
		(-1, -1, -1)	0.6, 0.5, 0.7	(395, 61, 3.1)
0	$Z_1 = 480$ $Z_2 = 70.5$ $Z_3 = 3.4$	(-5, -5, -5)	0.9, 0.85, 0.7	(477.5, 66.5, 3.25)
		(-3, -3, -3)	0.8, 0.7, 0.85	(480, 68, 3.35)
		(-2, -2, -2)	0.7, 0.65, 0.75	(480, 68, 3.35)
		(-1, -1, -1)	0.6, 0.5, 0.7	(480, 68, 3.35)
0.5	$Z_1 = 515$ $Z_2 = 76$ $Z_3 = 3.9$	(-5, -5, -5)	0.9, 0.85, 0.7	(530, 74, 3.9)
		(-3, -3, -3)	0.8, 0.7, 0.85	(530, 74, 3.9)
		(-2, -2, -2)	0.7, 0.65, 0.75	(530, 74, 3.9)
		(-1, -1, -1)	0.6, 0.5, 0.7	(530, 74, 3.9)

From the Table-V GA based hybrid approach with risk attitude parameter can effectively handles uncertainty (interval number) in the objective function of assignment problem.

GA based hybrid approach with risk attitude parameter provided situation wise efficient solution with sensitivity analysis to DM and many alternatives for DM to take decision in decision making process.

## 7. CONCLUSION

Genetic algorithm based hybrid approach provided the solutions of multi-objective interval assignment problem with risk attitude parameter using an exponential membership function with sensitivity analysis. GA based hybrid approach also provided situation wise all possible solution to take the decision for DM, which is highly beneficial for DM to take decision according to the situation.

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# Optimization of Process Parameters in Electrical Discharge Machining of DIN-X36CrMo17 Steel Using Grey Relational Analysis

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**Abstract:** The objective of this study was to determine the optimal setting of process parameters for electrical discharge machining (EDM) of DIN-X36CrMo17 tool steel using Grey relation analysis (GRA). The Grey relational analysis theory was used to resolve the complicated interrelationships among the multiple performance characteristics. The parameters considered were Peak current ( $I_p$ ), On-time ( $T_{on}$ ), Off-time ( $T_{off}$ ), Spark-gap and Flushing-height, whereas the response was Material removal rate (MRR) and Surface reference (SR). The optimal combination of parameters were determined through experiments, which were entirely based on Taguchi Method. In this experiment, three levels of each parameter had been taken into consideration using  $L_{27}$  orthogonal array to find out optimal setting of machining parameters for maximum material removal rate and minimum surface roughness. And finally, using MINITAB the relationship among the process parameters were determined.

**Keywords:** EDM, Taguchi Method, Surface Roughness, GRA

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## 1. INTRODUCTION

The role of Electrical Discharge Machining (EDM) as a machining process is crucial now in the manufacturing industry, because of its ability to machine any electrically conductive material, regardless of its mechanical strength, whereas the conventional machining processes finds it difficult to deal with hard to machine materials. EDM is the most basic of non-traditional machining process, wherein material is removed by thermal energy created by a spark occurring by means of repeated sequence of electrical ejections between the small gap of an electrode and a work piece. In any machining process, it is important to determine the optimal setting of process parameters and this study has attempted to determine the optimal setting of parameters for EDM of DIN-X36CrMo17 tool steel using Grey relation analysis (GRA).

## 2. LITERATURE REVIEW

P. Kuppan, A. Rajadurai, S. Narayan et al. (2007) studied the influence of operating parameters in case of Inconel 718. Chandramouli S et al. (2014) carried out a study on EDM process parameters by using the Taguchi method and selected an optimal result as part of the study. Gurtej Singh, Paramjit Singh, GouravTejpal, Baljinder Singh et al. (2012) presented a work on the effect of machining parameters on Surface roughness of H13 steel in EDM process using powder mixed fluid. In this work, Taguchi methodology was used for determining the effect of different machining parameters. Kamaljit Singh et al. (2013) conducted an experimental investigation of machining of OHNS Die steel by EDM process. Kapil Banker et. al. (2014) performed

Parameter Optimization of Electro Discharge Machine of AISI 304 steel using Taguchi Method. Surendar Kumar, SatpalKundu, Ravinder Chaudhary et al. (2014) conducted an experiment on MRR on H-13 Die Tool Steel using EDM with application of the Taguchi technique.

## 3. METHODOLOGY

### 3.1 Grey Taguchi Optimization

Grey analysis uses a specific concept of information. It defines situations with no information as black and those with perfect information as white. However, neither of these idealized situations ever occurs in real world problems. In fact, situations between these extremes are described as either being grey, hazy or fuzzy. Therefore, a grey system means that it is a system in which part of information is known and part of information is unknown. Grey analysis does not attempt to find the best solution, but does provide techniques for determining a good solution, an appropriate solution for real world problems.

**Stepwise procedure of GRA optimization include:**

- Identify the performance characteristics and machining parameters to be evaluated.
- Determine the number of levels for the process parameters.
- Select the appropriate orthogonal array and assign the machining parameters to the orthogonal array.
- Conduct the experiments based on the arrangement of the orthogonal array.

- Normalize the experiment results.
- Perform the grey relational generating and calculate the grey relational coefficient.
- Calculate the grey relational grade by averaging the grey relational coefficient.
- Analyze the experimental results using the grey relational grade.
- Select the optimal levels of machining parameters.
- Verify the optimal machining parameters through the confirmation experiment

#### Step 1: Normalization of the experimental data

It is the first step in the grey relational analysis, a normalization of the experimental data is performed to prepare raw data for the analysis where the original sequence is transferred to a comparable sequence. Linear normalization is usually required since the range and unit in one data sequence may differ from the others. The “smaller-the-better” is a characteristic of the original sequence, and it is used to compare levels here in the GRA. Then, the original sequence should be normalized as follows.

$$x_i^*(k) = \frac{\max x_i^o(k) - x_i^o(k)}{\max x_i^o(k) - \min x_i^o(k)} \quad (i)$$

#### Step 2: Determination of deviation sequences, $\Delta oi(k)$ .

The deviation sequence  $\Delta oi(k)$  is the absolute difference between the reference sequence  $x_o^*(k)$  and the

comparability sequence  $x_i^*(k)$  after normalization. It is determined using Eq. (ii) as:

$$\Delta oi(k) = |x_o^*(k) - x_i^*(k)| \quad (ii)$$

After ensuring that the normalization of the experimental data is done and the determination of standard deviation is found out for all 27 experiments, the grey relational coefficient was calculated.

#### Step 3: Calculation of grey relational coefficient (GRC)

GRC for all the sequences expresses the relationship between the ideal (best) and actual normalized experimental data. If the two sequences agree at all points, then their grey relational coefficient is 1. The grey relational coefficient  $\gamma(x_o^*(k), x_i^*(k))$  can be expressed by Eq. (iii) and shown in table III.

$$\gamma(x_o^*(k), x_i^*(k)) = \frac{\Delta \min + \xi \Delta \max}{\Delta oi(k) + \xi \Delta \max} \quad 0 < \gamma(x_o^*(k), x_i^*(k)) \leq 1 \quad (iii)$$

#### Step 4: Determination of grey relational grade (GRG)

The overall evaluation of the multiple performance characteristics is based on the grey relational grade. The grey relational grade is an average sum of the grey relational coefficients which is defined as follows: (given in table I)

$$\gamma(x_o^*, x_i^*) = \sum_{k=1}^n \beta k \gamma(x_o^*(k), x_i^*(k)), \quad \sum_{k=1}^n \beta k = 1 \quad (iv)$$

TABLE I: Grey relational grade

Expt. No	A Peak current	B On time	C Off time	D Sparking gap	E Flushing height	GRG	RANK
1	4	42	40	5	13	0.566671181	10
2	4	42	40	5	14	0.668625033	24
3	4	42	40	5	15	0.517595509	5
4	4	48	43	4	13	0.625191706	18
5	4	48	43	4	14	0.62190165	17
6	4	48	43	4	15	0.641761697	21
7	4	50	42	3	13	0.666354607	23
8	4	50	42	3	14	0.582547973	14
9	4	50	42	3	15	0.58111971	13
10	6	42	43	3	13	0.420243623	1
11	6	42	43	3	14	0.446143824	2
12	6	42	43	3	15	0.461957184	3
13	6	48	42	5	13	0.508199766	4



Expt. No	A Peak current	B On time	C Off time	D Sparking gap	E Flushing height	GRG	RANK
14	6	48	42	5	14	0.539469178	7
15	6	48	42	5	15	0.580705022	12
16	6	50	40	4	13	0.533056891	6
17	6	50	40	4	14	0.574235786	11
18	6	50	40	4	15	0.551197621	8
19	9	42	42	4	13	0.603759458	16
20	9	42	42	4	14	0.587334208	15
21	9	42	42	4	15	0.559692266	9
22	9	48	40	3	13	0.722515441	27
23	9	48	40	3	14	0.714697316	26
24	9	48	40	3	15	0.677909008	25
25	9	50	43	5	13	0.629631328	19
26	9	50	43	5	14	0.655368151	22
27	9	50	43	5	15	0.6377721	20

### 3.2 Taguchi Method

Developed by Dr. Genichi Taguchi of Japan, Taguchi method helps the manufacturer to produce high quality product at a low cost. This method involves using the orthogonal arrays to organize the parameters affecting the process and the different levels at which they are varied.

## 4. WORK PLAN

### 4.1 Selection of Process Parameters and Their Levels

For the current experimental work, five process parameters each at three levels have been decided. The levels of the individual parameters are as shown in the Table. II and is given below.

**TABLE II : Selection of process parameters and their levels.**

Factor	Parameters	Level 1	Level 2	Level 3
A	Peak Current ( $I_p$ )	4	6	9
B	On Time ( $T_{on}$ )	42	48	50
C	Off Time ( $T_{off}$ )	40	43	42
D	Sparking gap	5	4	3
E	Flushing height	13	14	15

Orthogonal array of  $L_{27}$  having 8 DOF was used for experimentation. For each test in the  $L_{27}$  array, the levels of the process parameters are shown in Table III

**TABLE III : Test results**

Expt. No	A Peak current		B On time		C Off time		D Sparking gap		E Flushing height	
	Actual	Coded	Actual	Coded	Actual	Coded	Actual	Coded	Actual	Coded
1	4	1	42	1	40	1	5	1	13	1
2	4	1	42	1	40	1	5	1	14	2
3	4	1	42	1	40	1	5	1	15	3

Expt. No	A Peak current		B On time		C Off time		D Sparking gap		E Flushing height	
	Actual	Coded	Actual	Coded	Actual	Coded	Actual	Coded	Actual	Coded
4	4	1	48	2	43	2	4	2	13	1
5	4	1	48	2	43	2	4	2	14	2
6	4	1	48	2	43	2	4	2	15	3
7	4	1	50	3	42	3	3	3	13	1
8	4	1	50	3	42	3	3	3	14	2
9	4	1	50	3	42	3	3	3	15	3
10	6	2	42	1	43	2	3	3	13	1
11	6	2	42	1	43	2	3	3	14	2
12	6	2	42	1	43	2	3	3	15	3
13	6	2	48	2	42	3	5	1	13	1
14	6	2	48	2	42	3	5	1	14	2
15	6	2	48	2	42	3	5	1	15	3
16	6	2	50	3	40	1	4	2	13	1
17	6	2	50	3	40	1	4	2	14	2
18	6	2	50	3	40	1	4	2	15	3
19	9	3	42	1	42	3	4	2	13	1
20	9	3	42	1	42	3	4	2	14	2
21	9	3	42	1	42	3	4	2	15	3
22	9	3	48	2	40	1	3	3	13	1
23	9	3	48	2	40	1	3	3	14	2
24	9	3	48	2	40	1	3	3	15	3
25	9	3	50	3	43	2	5	1	13	1
26	9	3	50	3	43	2	5	1	14	2
27	9	3	50	3	43	2	5	1	15	3

## 5. RESULTS AND CONCLUSIONS

This research work has focused on assessing the Electro Discharge Machining (EDM) behavior of DIN-X36CrMo17 tool steel as workpiece and copper as electrodes. The experiments were analyzed against the variation of some of the most important EDM parameters namely, current ( $I_p$ ), pulse on-time ( $T_{on}$ ), pulse off time ( $T_{off}$ ), flushing pressure ( $F_p$ ), and Sparking gap ( $V_g$ ) that influence the process performance. The measured technological outputs were Material Removal Rate (MRR) and Surface Roughness (SR). The most important conclusions of the work are summarized below: (as shown in figure I, figure II, figure III and figure IV)).

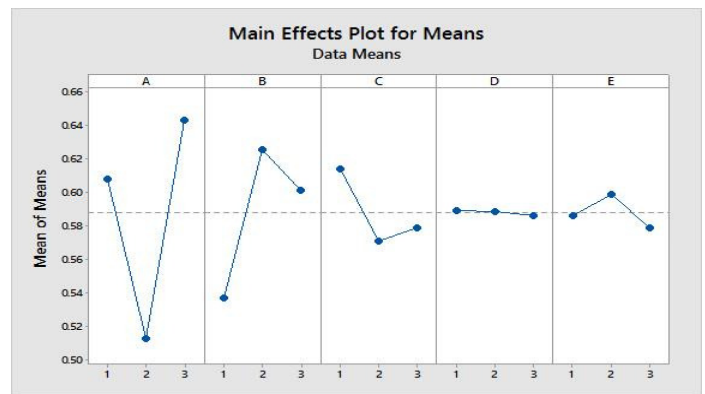


Fig. 1. Main effect plot

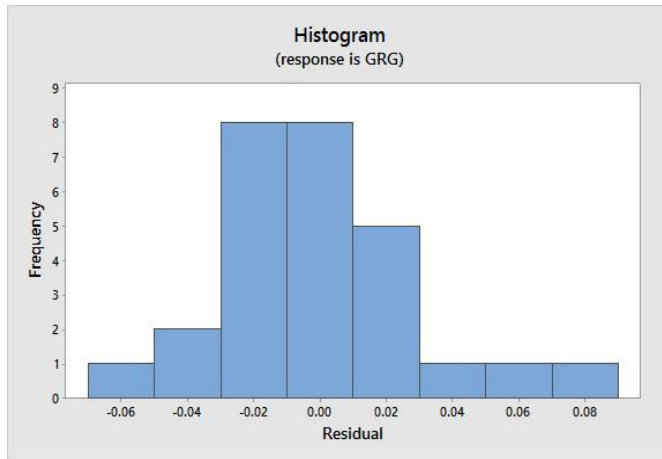


Fig. 2: Histogram

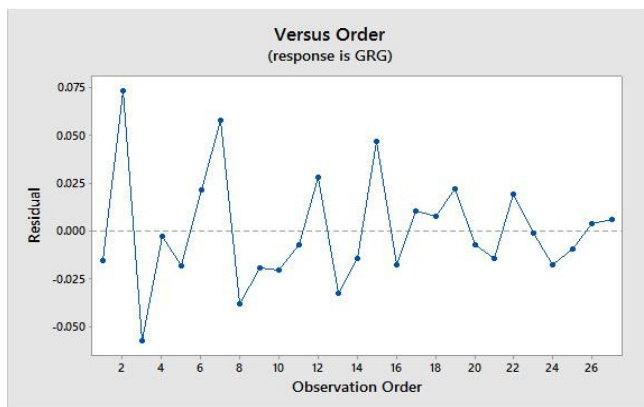


Fig. 3: Response GRG

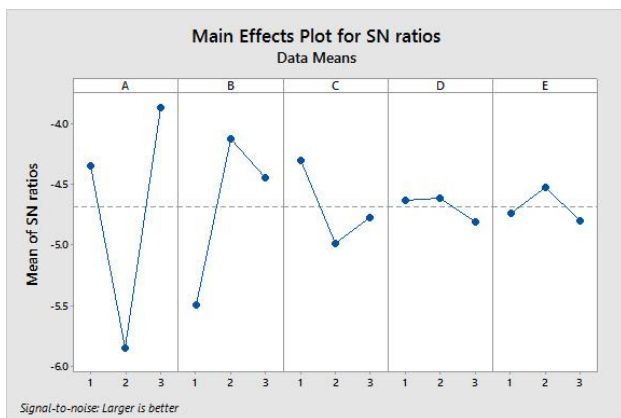


Figure IV: Main effect plot for SN ratios

- The optimal condition was found to be Peak current ( $I_p$ ):9A, On time ( $T_{on}$ ): 48 $\mu$ s, Off time ( $T_{off}$ ):40 $\mu$ s,Sparking gap ( $V_g$ ): 5A, and Flushing height( $T_{up}$ ): 14s.

It is concluded that the grey analysis can be effectively deployed for optimizing the multi-response problems in manufacturing industry.

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# Experimental Investigation of AFM by Using Response Surface Methodology Method and Parametric Optimization by Genetic Algorithm

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*Abstract: This paper concentrates on effect of various parameters pressure, number of cycle and mesh size on the surface roughness in abrasive flow machining (AFM) through experimentation on brass workpieces. A mathematical model was developed for relationship of various parameter with surface finish using response surface methodology(RSM). For optimization purpose, genetic algorithm (GA) has been used. The optimum model was created by comparison of experimental and GA result, the error found was less than 15%. It was found from result that number of cycle is the main parameter that affect the surface finish.*

*Keywords: Abrasive Flow Machining, Surface Roughness, RSM, ANOVA, Genetic Algorithm, Minitab17*

## 1. INTRODUCTION

Abrasive flow machining is an advanced nonconventional machining process which is used to measure the Quality of surface by measuring the surface roughness of parts. Many of industries like aerospace, automobile and medical instruments use abrasive flow machine for surface finishing. Yadav et al. [1] describe about the abrasive flow machine application. AFM is a non-traditional finishing process which is used for radius edges or polish, surface finish of internal passage, finishing of complex geometries.

First research on AFM is conducted by Rhoades[2], In research variation of pressure, number of cycle and mesh number with surface finish is discussed. RSM is used by doing 20 experiments on the workpiece under different machining condition. The best machining condition is found by genetic algorithm. It was founded by Kar et al[3] that abrasive concentration and number of cycle are common parameters to input.

In the present researches investigations are carried on the hard to machinable materials. In the investigation of AFM research is carried on minimizing the processing time, total cost and energy requirement. For increasing workpiece and abrasive connection Walia[5] used triangular CFG type of rod to spin the abrasive media

## 2. EXPERIMENTAL SETUP

AFM set up is shown below. To produce required pump rotation electric motor was used. Between lower and upper plate workpiece was fixed.

There are many components used in AFM just like pressure gauge, pump, electric motor, piston, oil reservoir. Pump delivers pressure of oil to piston in the cylinder. Pipe

carrying oil has sufficient strength to withstand high pressure of oil.



Fig. 1. Experimental diagram of AFM.



Fig. 2. Brass workpiece

Cleaning of workpiece was done after and before the process. Brass was used as workpiece material. Drilling operation is used to hole in the workpiece. Mixture of particles of abrasive, polymer and gel was used as abrasive medium. 1:1:1 ratio was used for mixing these elements. Aluminium oxide was used as abrasive material.

### 3. EXPERIMENTAL WORK

Percentage increase in surface finish is given by the formula shown below

$$\Delta Ra\% = \frac{\text{roughness before AFM} - \text{roughness after AFM}}{\text{roughness before AFM}}$$

L20 array in response surface methodology was used for design of experiments. The three factors pressure, number of cycles and mesh number were varied according to requirement. With increasing number of experiments RSM result has high accuracy.

**TABLE I: Process parameter**

Sr. number	Factor	Range	Unit
1	No. of cycles	100-500	No
2	Pressure	10-40	kgf/cm ²
3	Mesh number	80-220	No
4	Initial Ra	2.20-2.90	Mm
5	Ratio of gel polymer	1:1	Weight percentage
6	Media abrasive ratio	1:1	Weight percentage

### 4. EXPERIMENTAL DESIGN

In this RSM design we are using L20 orthogonal array. Based on this L20 design experiments are carried on. For

this L20 design in RSM, there were 20 workpieces. So, there were 20 experiments done on 20 different workpieces on different machining condition of pressure, number of cycle and mesh number.

**TABLE II: Response analysis**

8	Pt Type	Blocks	Pressure	No. of cycle	Mesh size	ΔRa
1	0	1	25	300	120	1.4
2	-1	1	40	300	120	1.25
3	0	1	25	300	120	0.92
4	-1	1	25	300	220	1.84
5	1	1	40	100	220	0.99
6	1	1	40	500	80	1.01
7	1	1	40	500	220	0.94
8	-1	1	25	100	120	1.43
9	0	1	25	300	120	1.47
10	0	1	25	300	120	1.58
11	-1	1	10	300	120	1.42
12	1	1	10	500	220	1.29
13	0	1	25	300	120	0.98
14	1	1	10	500	80	1.98
15	0	1	25	300	120	0.83
16	-1	1	25	500	120	0.79
17	1	1	10	100	80	1.51
18	-1	1	25	300	80	1.46
19	1	1	40	100	80	1.6
20	1	1	10	100	220	1.44

## 5. RESULT AND DISCUSSION

### 5.1 Effect of pressure on $\Delta Ra$

Pressure has significant effect on  $\Delta Ra$ . With increasing pressure from 10kgf/cm² to 40kgf/cm²  $\Delta Ra$  value increased approximately linear. With increasing pressure abrasive particle indentation depth is increased in workpiece material so more roughness is removal by these abrasive particles. Due to low pressure there is low pressure force on the surface irregularities on the workpiece so low roughness is removed by abrasive particles.

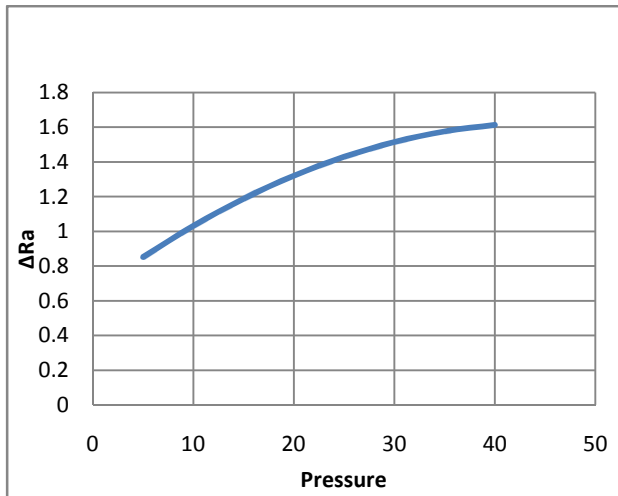


Fig. 3.  $\Delta Ra$  VS PRESSURE

### 5.2 Effect of number of cycle

In these experiments number of cycles vary from 100 to 500. It was seen that with increasing number of cycle  $\Delta Ra$  value increased upto 500 cycles. But after 300 cycles increase in  $\Delta Ra$  value slow down. This is because material removal capability decreased with increase in number of cycle.

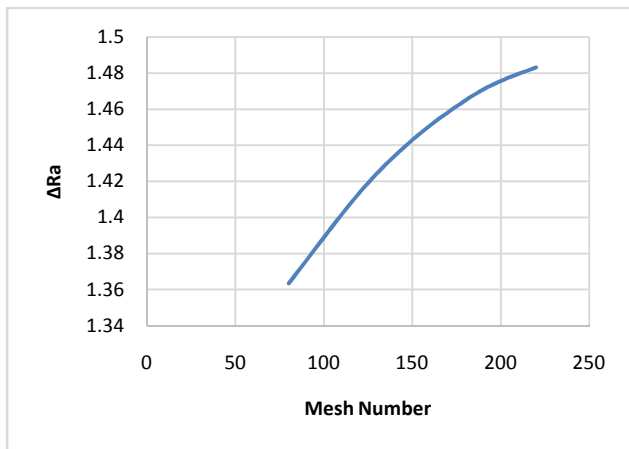


Fig. 4.  $\Delta Ra$  VS NUMBER OF CYCLE

### 5.3 EFFECT OF MESH SIZE ON $\Delta Ra$

It was seen from the graph that with increase in mesh number upto near 220,  $\Delta Ra$  value was also increasing. But after increasing mesh number increase in  $\Delta Ra$  value tend to slow down. This decrease due to fact that with increase in mesh number there are fine abrasive present. So these fine abrasive has low cutting capacity and low roughness was removed by these abrasive particles. But when mesh number was low near 80 then there were present large size of abrasive particles and these large abrasive particle littly impair the surface so less surface finish was obtained at low mesh number.

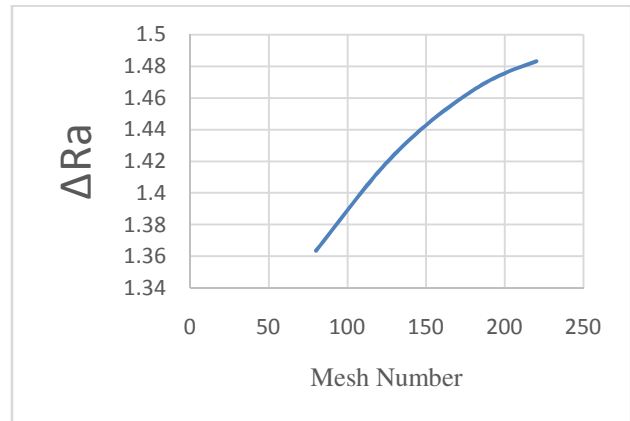


Fig. 5.  $\Delta Ra$  VS MESH NUMBER

### 5.4 ANALYSIS OF VARIANCE(ANOVA)

Model summary shows that  $R^2$  (adj.) value was 97.57%. It was mean that result was near approximately significant result. 0.0521283 was the value of standard deviation of residual. Result has significant value because p value was less than 5%. More than 5% of critical value obtained for F-value.

TABLE III: Model Summary

S	R-sq.	R-sq.(adj)	R-sq.(prd.)
0.0521283	98.72%	97.57%	91.94%

### 5.5 ANALYSIS BY GENETIC ALGORITHM FOR OPTIMIZATION

To apply genetic algorithm(GA) at first fitness function was created.

Fitness function is given by

function [ Z ] =

$Ra(x)Z = 0.186 + 0.02095 * x(1) + 0.002306 * x(2) + 0.00173 * x(3) - 0.000475 * x(1) * x(1) -$

$0.000003 * x(2) * x(2) -$

$0.000004 * x(3) * x(3) + 0.000052 * x(1) * x(2) + 0.000049 * x(1) * x(3) - 0.000003 * x(2) * x(3) \dots (i)$

**TABLE IV: Genetic Algorithm Parameters**

Variable	Optimum Value
Population size	20
Max. number of generation	51
Crossover probability	0.8/scattered
Mutation probability	Constrained dependent/0.1
Selection Operator	Stochastic Uniform as selection function and tournament selection
Tournament Size	4
Elite Count	2
Crossover Function	Scattered
Penalty Factor	100
Initial Generation	100

So, it is found that optimize value of pressure, number of cycle and mesh number are 10, 100 and 80 respectively. Output result has optimized value as 0.7286. 51 iterations are performed by GA to optimize the result. Initial population is selected as 20.

#### 5.5.1 MODEL CHECKING FOR OPTIMIZATION OF SINGLE OBJECTIVE FUNCTION:

➤ To find the error formula is given as

$$\text{Prediction Error} = \frac{\text{GA Predicted Result} - \text{Experimental Result}}{\text{GA Predicted Result}} \times 100$$

**TABLE V: % ERROR IN MODEL**

Predicted Ra through GA	Verification by Experiments
Pressure=10 No. of Cycle=100 Abrasive Size=80 R _a predicted = .7286	Pressure=10 No. of Cycle=100 Abrasive Size=80 R _a actual = 1.460

$$\% \text{ error} = \frac{(\text{GA predicted} - \text{actual experimental}) * 100}{\text{GA Predicted}}$$

## 6. CONCLUSION

- It was seen from experimental results that  $\Delta R_a$  value increasing with increasing in the pressure upto 40kgf/cm². It means that  $\Delta R_a$  is increasing with pressure upto a certain pressure.
- It was found that  $\Delta R_a$  value increases upto 500 cycles approximately linear. After 500 cycles increase in  $\Delta R_a$  value slow down.

- $\Delta R_a$  value increasing with mesh number of abrasive upto certain mesh number which was 220. After 220 mesh number increase in  $\Delta R_a$  value slow down.
- GA optimize the parameter with value of 10, 100 and 80 which are pressure, number of cycle and mesh number respectively.
- The output optimized result was 0.7286 which is the value of change in surface roughness.
- Model checking for error produce a result which was less than 15%. It means that GA was successfully applied for optimization.

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# An Integrated Modified Kano Model, QFD and TOPSIS Method for Supplier Selection

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**Abstract:** Supplier selection is a strategic decision for industries and hence for better supplier assessment, larger set of criteria need to be considered by decision makers. Further criteria need to be classified on their significance level to enable decision makers to choose appropriate set of criteria for selection. In this work an integrated methodology has been proposed which considers thirty six criteria for selection and facilitate decision makers to categorize according to significance. In this paper an integrated approach of Kano model, QFD and TOPSIS is applied for selection of the potential supplier's. Kano model has been used to find out the appropriate set of the criteria's and weights of criteria are assigned by modified Kano method. QFD is applied to determine the relationship between the criteria's as desired by the industry and the criteria's over which the suppliers will be assessed. Finally TOPSIS method is used for ranking of the potential supplier's.

**Keywords:** Kano model, Quality Function deployment, TOPSIS, Supplier selection

## 1. INTRODUCTION

Today because of globalized markets industries are under immense pressure to provide the customer with a high quality product at lowest possible cost with minimum lead time to increase the customer satisfaction. In achievement of these objectives of industries, suppliers play a major role therefore identification of right suppliers is crucial. Identification and selection of suppliers involves consideration of various qualitative and quantitative criteria which makes supplier selection a multi-criteria decision making (MCDM) problem (Jain et al., 2016; Jain and Singh, 2017). Authors have proposed various methodologies for supplier selection but less attention has been given to criteria identification for supplier selection process. Criteria selection and classification is basic and vital step in selection process over which success of selection process depends. Selection of appropriate criteria also increases the customer satisfaction level.

In the literature most of the authors have addressed the supplier selection problem by considering few of the criteria as reported by Dickson. Aksoy et al., (2014) considered 3 criteria's, Kar (2014) considered 10 criteria's, Ware et al., (2014) accounted 4 criteria's, Jadidi et al., (2014) considered 5 criteria's, Qian (2014) considered 4 criteria's, García et al., (2013) consider 3 criteria's, Rajesh

and Malliga (2013) considered only 3 out of 23 criteria reported by Dickson. Furthermore these criteria's are selected by the expert's from the industry or the academia, based over their experience therefore there is a need of a methodology/philosophy that can provide different sets of criteria's for selection of potential suppliers.

Therefore to address the objective of consideration of larger set of selection criteria, an integrated methodology is presented which considers thirty six criteria and its classification in to different categories. Further methodology assigns weight assignment to most essential criteria finally asses' suppliers and assigns ranks. In the present work, philosophy of Kano model is used, to find out different set of appropriate criteria's from all the thirty six criteria's as depicted in table I. Among them, most essential criteria or Must be criteria's of Kano model are considered as assessment criteria's for potential suppliers because these properties are minimum required which must be fulfilled by the suppliers. Must be category set of criteria's are assigned weights by the modified Kano method (Chaudha et al., 2011). Furthermore QFD has been applied to determine the relationship between the selected set of criteria and the characteristics of the suppliers. Finally TOPSIS method which is a practical and useful technique for ranking and selection is applied for ranking and selection of the potential suppliers

TABLE I

Quality	Technical capability	Management and organization	Labor relations record	Reliability	Professionalism
Delivery	Financial position	Operating controls	Geographical location	Flexibility	JIT

Quality	Technical capability	Management and organization	Labor relations record	Reliability	Professionalism
Performance history	Procedural compliance	Repair services	Amount of past business	Process Improvement	Commitment
Warranties and claim policies	Communication system	Attitude	Training aid	Product Development	Economy Situation
Production facilities	Reputation and position in the industry	Impression	Reciprocal arrangement	Environment And Social Responsibility	Long Term Relationship
Net price	Desire to do business	Packaging ability	Reliability	Occupational Safety And Health	Political Situation

The organization of the paper is as follows: the next section describes the computational procedure for Kano model. Third and fourth section covers the procedural steps of QFD and TOPSIS method respectively. Fifth section represents the proposed procedure. Section six covers results and discussion. Conclusions are taken up in seventh section.

## 2. KANO MODEL

### 2.1 Theory of Attractive Quality (Kano's Model)

Kano et al., (1984) adapted 'Motivation-Hygiene Theory' and proposed a two way model on quality known as theory of attractive quality. Kano model is based on customer's experience and perception and focuses on most important attributes of the product. The theory of attractive quality classifies the customer requirements in to five different sets. The five sets of Kano model are:-

- Must-be requirements (M)*: These are the essential requirements which customer need to have in the product.
- One-dimensional requirements (O)*: Fulfillment of these requirements is proportional to the customer satisfaction level i.e. customer satisfaction increases if these requirements are fulfilled at higher level and vice versa.
- Attractive requirements (A)*: Fulfillment of these requirements has highest level influence on the customer satisfaction where as non fulfillment of these requirements does not increase dissatisfaction level.

iv. *In different requirements (I)*: Customer satisfaction level is not influenced by the achievement or non achievement of these requirements.

v. *Reverse requirements (R)*: Customers do not want these attributes in the product and absence of these attributes increases customer's satisfaction level.

### 2.2 Customer satisfaction coefficients

Berger et al., (1993) proposed customer satisfaction (CS) coefficient. The coefficient indicates the level of customer satisfaction or dissatisfaction in quantitative values. CS coefficient values states whether customer satisfaction increases or decreases when a product attribute is fulfilled. CS coefficients are calculated by equations:-

$$\text{Satisfaction index (SI)} = \frac{A+O}{A+O+M+I} \quad \text{and} \quad \text{Dissatisfaction index (DI)} = - \frac{O+M}{(A+O+M+I)}$$

### 2.3 Steps of Kano Model

The present research utilized the analogy that the decision-makers viewpoint is customer's viewpoint. The dimensions of the model are the criteria's for supplier assessment. Hence Kano model analogy is applied in this research for categorization of criteria's in to different sets. (Avikal et al., 2014)

*Step 1*: A questionnaire is a formed incorporating both functional and dysfunctional form of questions for thirty six criteria's.

TABLE II: Kano Evaluation Table (Berger et al 1993)

Customer Requirements		Dysfunctional				
		Like	Must-be	Neutral	Live with	Dislike
Functional	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

*Step 2: Kano et al., (1984)* proposed an evaluation table for the analysis of the responses from the customers table II. Combining the responses of the both the functional and dysfunctional form of questions results are obtained.

*Step 3:* All the questionnaires responses are analyzed and the frequencies of all the six categories is tabulated and counted. SI and DI are calculated for each criterion and based on SI and DI values; Kano category of the criteria's is decided.

*Step 4: Chaudha et al.,( 2011)* made adjustment in the traditional improvement ratio and proposed a function  $IR_{adj} = (1 + m)^k \times (IR_0)$

Where  $IR_{adj}$  denotes adjusted improvement ratio and  $IR_0$  denotes traditional improvement ratio,  $m = \max(|SI|, |DI|)$  and the value of  $k$  is taken 0 for 'must be' category, 0.5 for 'one dimensional' category and 1.5 for 'attractive requirements'.

### 3. QUALITY FUNCTION DEPLOYMENT

In late 1960's, QFD was developed by Professors Shigeru Mizuno and Yoji Akao in Japan. QFD is a customer oriented approach through which customer requirements (WHAT's) are identified and are translated to product design attributes (HOW's) (Govers, 1996). The customer requirements are the voice of customer (VoC) where in customer expresses its needs in words (Prasad et al., 1998). Further a matrix, known as House of Quality (HoQ) is framed to convert VoC into voice of engineers.

In supplier selection process the voice of industry becomes VoC as suppliers supply material to the industries and industry act as customer. Certain requirements are desired by the industry from the suppliers and these requirements are considered as criteria for supplier selection. The criteria's importance is decided depending over the criticality and need of the criteria. On the basis of expected level of supplier performance, a target value is set for each criterion. A modified improvement ratio is used and multiplied by the importance of each criteria and final relative weight of the criteria is calculated. Later in the process of QFD, HOW's are decided for meeting the WHAT's criteria for selection. Further the house of quality is constructed showing the relationship between requirements as per the VoC and product attributes to full fill these requirements.

### 4. TOPSIS

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method developed by Hwang and Yoon (Hwang, 1981). The basic concept of TOPSIS method is that the final selected alternative should have the shortest distance from

the ideal solution (zenith) and the farthest distance from the negative-ideal solution (nadir) in some geometrical sense. A positive ideal solution (PIS) comprises of maximum of all the benefit criteria and minimum of the cost criteria, whereas a negative ideal solution (NIS) comprises of maximum of the cost criteria and minimum of the benefit criteria (Olson, 2004). In this study TOPSIS method is used for final ranking of the suppliers based over which potential suppliers can be identified.

### 5. THE PROPOSED PROCEDURE

In present work identification of potential supplier's has been done by integrated MCDM approaches. Thirty six criteria have been considered for the study and they are evaluated by the theory of attractive quality. A questionnaire based on Kano model has been framed for criteria classification in to different sets. 72 questions are framed covering both functional and dysfunctional aspects of each criterion. Responses from 06 personnel's representing middle and upper management of iron and steel industries are collected. Further more on the basis of the responses criteria's are classified in to Kano sets. In this study, set of Must be criteria's are considered for potential supplier selection because these criteria's are the minimum requirements which must be fulfilled by suppliers. Weights of selected criteria's are assigned by adjusted improvement ratio. After Kano classification and weight assignment of the criteria's QFD has been applied. In QFD the criteria of the Must be set becomes internal variables (WHAT's) as the company itself is acting as a customer while selecting the potential supplier's. Through literature survey the suppliers attributes or external variables (HOW's) have been identified. A relationship matrix is developed to find the impact of HOW's on each WHAT and weights are assigned to HOW's. Finally, after calculation of the weights of the HOW's, TOPSIS method has been used for ranking the suppliers.

Step 1: Identification of Criteria's for Supplier Selection from literature.

Step 2: Categorization of criteria's in to Kano sets.

Step 3: Identification of WHAT's (criteria's) for QFD.

Step 4: Determination of HOW's for QFD.

Step 5: Determination of weights to HOW's through QFD

Step 6: Evaluation of scores of the suppliers through TOPSIS.

Step 7: Final ranking of the suppliers.

### 6. RESULTS AND DISCUSSION

On the basis of responses collected and analysed ten criteria in the Must be category have been identified . they are i) Quality (C1) ii) Delivery (C2) iii) Price (C3) iv)

technical capability (C4) v) Procedural Compliance (C5) vi) Reputation and positioning in industry (C6) vii) Attitude (C7) viii) Reliability (C8) ix) Professionalism (C9) x) Commitment. (C10).Traditionally weights were assigned to the criteria by using the formula

$$IR_o = \frac{TCC}{CCS}$$

Where TCC denotes target customer satisfaction and CCS denotes current customer satisfaction Self stated importance is the average value of self importance given by the industry to each criterion for identification of potential suppliers. The target value for the criteria is the highest value which is achieved by any of the existing suppliers. The adjusted improvement ratio has been calculated using SI and DI index values and different values of k depending over the Kano category classification. The relative importance of the criteria is shown in table III.

**TABLE III: Relative importance of criteria's**

Criteria	Self-stated importance	SI	DI	m= MAX(SI,DI)	Current supplier Criteria rating	Target	Improvement ratio (traditional)	Adjusted improvement Ratio	Adjusted importance	Relative importance
(C1)	4.625	0.375	1	1	3	4	1.33	1.881	8.699	11.952
(C2)	4.125	0.125	0.75	0.75	2	3	1.5	1.984	8.185	11.246
(C3)	4.375	0.25	0.875	0.875	4	4	1	1.369	5.991	8.231
(C4)	4.125	0.375	0.75	0.75	2	3	1.5	1.984	8.185	11.246
(C5)	3.625	0.125	0.5	0.5	2	4	2	2.449	8.879	12.200
(C6)	3.625	0.3	0.5	0.5	3	4	1.33	1.629	5.905	8.113
(C7)	3.575	0.25	0.525	0.525	2	3	1.5	1.852	6.622	9.098
(C8)	3.75	0.125	0.625	0.625	3	4	1.33	1.695	6.358	8.735
(C9)	3.7	0.25	0.625	0.625	4	4	1	1.275	4.717	6.480
(C10)	4.5	0.375	0.875	0.875	2	3	1.5	2.054	9.243	12.699

## 6.2 Determination of Final Ranking of Suppliers

The final ranks of the suppliers are calculated by TOPSIS method with the weights that have been determined through QFD. Decision matrix has been established and calculations are done for normalized decision matrix using vector normalization as shown in table VI. Calculations for weighted normalized decision matrix is shown are shown in

## 6.1 Determination of WHAT's and HOW's for QFD

After review of the available literature on supply chain management (SCM) and supplier selection (SS) seven attributes (TA's) are identified for supplier selection. The seven attributes identified are i) Quality system certification ii) Experience in the field iii) Innovation capability iv) Financial capability v) Demand flexibility vi) Location vii) Communication. Based on these attributes ten suppliers of the industry are assessed. The experts of the industry are asked to provide their opinion on the impact of each TA on each criterion (CN). The experts used the linguistic term as low, medium and high to give the impact of TA's on each criterion. The linguistic response of the experts has been converted in to numerical values as 1 for low, 5 for medium and 9 for high. The relationship matrix between the criteria and technical attributes has been established and relative weights of HOW's are calculated. Relationship matrix is shown in table IV.

table VII. The relative closeness ( $P_i^*$ ) of each alternative  $A_i$  with respect to  $A^+$  is calculated. The similarity to the ideal solution for each supplier has been calculated accordingly and shown in table VII. Final ranking of the suppliers has been determined based over the relative closeness and shown in table VII. The alternatives are ranked according to their relative closeness. The final ranking of the suppliers is  $S2>S3>S9>S8>S7>S4>S5>S1>S10>S6$ .

**TABLE IV: Relationship Matrix**

HOW's									
WHAT's	Importance	Quality system certification	Experience in the field	Innovation capability	Financial stability	Demand flexibility	Location	communication	TOTAL
(C1)	11.952	107.568	59.76	11.952	59.76	11.952	0	11.952	262.944
(C2)	11.246	11.246	56.23	0	56.23	101.214	101.214	56.23	382.364
(C3)	8.231	41.155	8.231	41.155	41.155	41.155	74.079	0	246.93
(C4)	11.246	101.214	56.23	56.23	56.23	56.23	0	0	326.134
(C5)	12.2	0	0	0	0	0	0	109.8	109.8
(C6)	8.113	40.565	73.017	40.565	40.565	0	0	0	194.712
(C7)	9.098	45.49	9.098	9.098	0	0	0	9.098	72.784
(C8)	8.735	43.675	78.615	43.675	0	0	0	0	165.965
(C9)	6.48	0	32.4	0	0	0	0	32.4	64.8
(C10)	12.699	12.699	0	0	0	0	0	0	12.699
Relative Weights		403.61	373.58	202.67	253.9	210.55	175.29	219.48	1839.13
Normalized weights		0.219	0.203	0.110	0.138	0.114	0.095	0.119	

**TABLE V: Weighted Normalized decision matrix for TOPSIS method**

	Quality system certification	Experience in the field	Innovation capability	Financial stability	Demand flexibility	Location	Communication
S1	0.03574	0.05880	0.00665	0.03894	0.03444	0.03706	0.03162
S2	0.10721	0.08232	0.04652	0.00779	0.02066	0.00529	0.04427
S3	0.05956	0.10584	0.03323	0.03894	0.00689	0.01588	0.05692
S4	0.08338	0.01176	0.01994	0.07009	0.04821	0.02647	0.01897
S5	0.03574	0.05880	0.00665	0.05452	0.04821	0.03706	0.03162
S6	0.01191	0.03528	0.04652	0.02336	0.03444	0.02647	0.03162
S7	0.08338	0.08232	0.01994	0.00779	0.00689	0.04765	0.05692
S8	0.10721	0.01176	0.03323	0.05452	0.02066	0.01588	0.04427
S9	0.05956	0.08232	0.05981	0.03894	0.06198	0.03706	0.01897
S10	0.03574	0.03528	0.03323	0.05452	0.03444	0.02647	0.00633

**TABLE VI: Separation distance and relative closeness and final ranks of suppliers**

S.No	Supplier	Si-	Si+	PI*	Ranks
1	S1	0.07254	0.11630	0.384135	8
2	S2	0.13811	0.08049	0.631793	1
3	S3	0.12793	0.08423	0.602988	2
4	S4	0.10716	0.11439	0.483683	6
5	S5	0.08616	0.11058	0.437938	7
6	S6	0.06506	0.13516	0.324943	10
7	S7	0.11324	0.10687	0.51447	5
8	S8	0.12087	0.10853	0.526896	4
9	S9	0.11980	0.07901	0.602585	3
10	S10	0.07224	0.12167	0.372544	9

## 7. CONCLUSIONS

The proposed methodology can be applied by decision makers to eliminate non potential suppliers at the initial stages of scrutiny to have more potential suppliers for final selection at later stages. The proposed methodology has three merits as compared to the previous MCDM methodologies, (i) in this work thirty six criteria's have been considered for supplier selection. Classification of these criteria's in to various Kano sets helps decision makers to have stage wise selection process of potential suppliers. (ii) The proposed methodology helps the academicians and industry decision makers to consider the most necessary and vital criteria for supplier selection. (iii) The present methodology make available to decision makers a tool to handle larger number of criteria , which makes supplier assessment more effective. In future research fuzzification of methods can be applied for capturing the vagueness in decision makers.

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# Solution of A Fokker-Planck Equation By Successive Linearisation Method

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**Abstract :** In this article, a Fokker-Planck equation of a vertical groundwater recharge in unsaturated porous media has been discussed, which gives a nonlinear partial differential equation in moisture content as a governing equation. The governing equation has been solved by a newly developed successive linearisation method (SLM), which is a very effective method. It's numerical and graphical representation is presented by using MATLAB.

**Keywords:-** Fokker-Planck equation, Groundwater recharge, Successive linearisation method.

## NOMENCLATURE:

$\theta(z, t)$	Moisture Content
$z$	Depth in the vertical downward direction of a flow
$t$	Time
$a, b, \beta, \gamma, \lambda$	Constants
$D(\theta)$	Soil water diffusivity coefficient
$K(\theta)$	Coefficient of the volumetric water content
$L$	Length of a large basin
$\vec{V}$	Volume flux of the moisture
$\nabla H$	Gradient of the whole moisture potential
$\rho_s$	Bulk density of the soil on dry weight basis
$M$	Mass of flux of the water at any time $t \geq 0$
$\phi$	Porosity
$S$	Saturation of soil
$\rho$	Flux density
$g$	Gravitational constant
$\eta$	Parameter
$K$	Order of SLM approximation
$r$	Order of differentiation

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## 1. INTRODUCTION

The Fokker-Planck equation is a partial differential equation that describes the time evolution of a probability density function of the velocity of a particle under the

influence of drag forces and random forces, as in Brownian motion (Leo, 2000). This equation is given by Adriaan Fokker (Fokker, 1914) and Max Planck (Planck, 1917) and is also known as the Kolmogorov forward equation, after



Arndrey Kolmogorov, who independently discovered the concept in 1931 (Kolmogorov, 1931).

Here we have discussed the Fokker-Planck equation arising in a vertical groundwater recharge in unsaturated porous media. Groundwater recharge (Allison, Gee and Tyler, 1994) is a hydrologic process where water moves downward from surface water to groundwater. It is a primary method through which water enters into an aquifer. This process usually occurs in the unsaturated zone below plant roots and is often expressed as a flux to the water table surface (the upper surface of the saturation zone). It has a great influence on rainfall, runoff, transpiration of plants, evaporation from the soil surface, infiltration, etc. It is very important to know about groundwater storage, so that we have to find a solution of the Fokker-Planck equation.

Many researchers discussed this problem with different viewpoints. Parikh, Mehta and Pradhan (2012) found a transcendental solution of the Fokker-Planck equation of vertical groundwater recharge in unsaturated homogeneous porous media. Patel, Mehta and Singh (2013) applied Homotopy Analysis method [HAM] to determine pressure head in the unsaturated soil during the infiltration phenomenon. Choksi and Singh (2017) studied on an infiltration phenomenon by Homotopy Perturbation Sumudu transform method (HPSTM). Borana, Pradhan and Mehta (2013) gave a numerical solution of the Boussinesq equation arising in one-dimensional infiltration phenomenon by using the finite difference method. Swartzendruber used Philip's method (Philip and Knight, 1974) to get a graphical illustration of the mathematical solution for horizontal water function. Using the singular Perturbation technique, Mehta (1975) provided an approximate solution, where the change in average diffusivity coefficient is being very small; it has been treated as a constant. H. A. Basha (1999) worked on multidimensional linearized nonsteady infiltration with prescribed boundary conditions at the soil surface. Van Genuchten (1980) developed other functions for practical applications of this problem.

## 2. STATEMENT OF THE PROBLEM

Consider the unsaturated flow in a vertical downward direction up to the length of a large basin  $L$  in a homogeneous porous medium and neglect the flow spreading in the other directions (Parikh, Mehta and Pradhan, 2012). There is no air resistance to the flow (i.e. The porous medium contains only the flowing liquid water and empty voids of air). The air in the void space is approximately at atmospheric pressure. Consider the moisture content at the soil surface as a time-dependent function. So applying the standard laws as Darcy's law (Darcy, 1856) and the continuity equation (Bear and Bachmat, 1990), we get a one-dimensional nonlinear partial differential equation as a governing equation.

The purpose of this article is to discuss the solution of a nonlinear Fokker-Planck equation arising in the groundwater recharge phenomenon (Fig.1) and to examine the moisture content in homogeneous porous media. The change in moisture content and distribution of pore pressure has been calculated using the successive linearisation method (SLM).

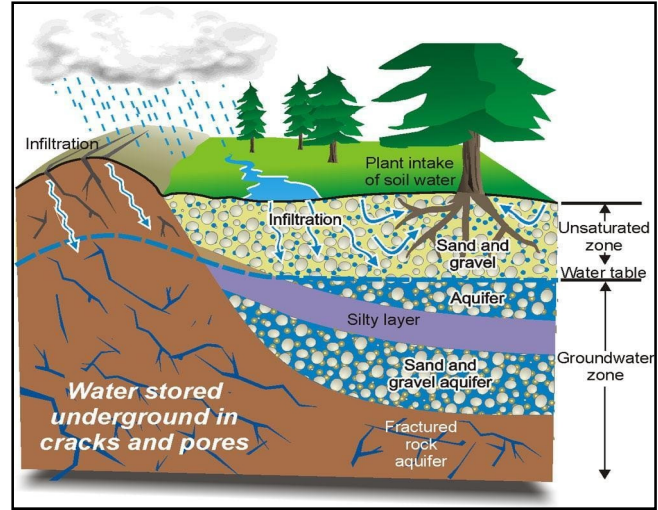


Fig. 1. Representation of groundwater phenomenon

## 3. MATHEMATICAL STRUCTURE OF THE PROBLEM

According to Darcy's law (Darcy, 1856), we can write

$$\vec{V} = -K(\theta)\nabla H \quad (i)$$

The equation of continuity for unsaturated porous media is given by

$$\frac{\partial}{\partial t}(\rho_s \theta S) = -\nabla M \quad (ii)$$

Consider that the water is incompressible and moisture content (Bear, 1972) is  $\theta = \theta S$ .

By the equation (ii), we get

$$\frac{\partial}{\partial t}(\rho_s \theta) = -\nabla(\rho \vec{V}) \quad (iii)$$

By the equations (i) and (iii), we get

$$\frac{\partial}{\partial t}(\rho_s \theta) = -\nabla(\rho(-K(\theta)\nabla H)) \quad (iv)$$

Assume that the flow is in the vertical downward direction (Scheidtger, 1974). Then from the equation (iv), we get

$$\rho_s \frac{\partial \theta}{\partial t} = \rho \frac{\partial}{\partial z} \left( K(\theta) \frac{\partial H}{\partial z} \right) \quad (v)$$

For unsaturated porous media  $H$ , total soil moisture potential (Scheidtger, 1974) is  $H = \psi + gz$ .

By the equation (v), we get

$$\frac{\partial \theta}{\partial t} = \frac{\rho}{\rho_s} \frac{\partial}{\partial z} \left( K(\theta) \frac{\partial \psi}{\partial z} \right) + \frac{\rho}{\rho_s} g \frac{\partial K(\theta)}{\partial z} \quad (\text{vi})$$

Rewriting the above equation as

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left( D(\theta) \frac{\partial \theta}{\partial z} \right) + \frac{\rho g}{\rho_s} K'(\theta) \frac{\partial \theta}{\partial z} \quad (\text{vii})$$

$$\text{where } D(\theta) = \frac{\rho K(\theta)}{\rho_s} \frac{\partial \psi}{\partial \theta} \text{ and } K'(\theta) = \frac{dK}{d\theta}$$

The equation (vii) is called one-dimensional Fokker-Planck equation.

By Broadbridge and White model (Broadbridge and White, 1988), the soil water diffusivity  $D(\theta)$  and hydraulic conductivity  $K(\theta)$  can be written as

$$D(\theta) = \frac{a}{(b-\theta)^2} = \frac{a}{b^2} \left( 1 + \frac{2\theta}{b} \right), \text{ since } \theta \text{ being very small,} \quad (\text{viii})$$

$$K(\theta) = \beta + \gamma(b - \theta) + \frac{\lambda}{2(b-\theta)} = \beta + \gamma b + \frac{\lambda}{2b} + \left( \frac{\lambda}{2b^2} - \gamma \right) \theta \quad (\text{ix})$$

By the equations (vii), (viii) and (ix), we get

$$\frac{\partial \theta}{\partial t} = \frac{a}{b^3} \frac{\partial}{\partial z} \left( (b + 2\theta) \frac{\partial \theta}{\partial z} \right) + \frac{\rho g}{\rho_s} \left( \frac{\lambda}{2b^2} - \gamma \right) \frac{\partial \theta}{\partial z} \quad (\text{x})$$

The equation (x) is a nonlinear second order partial differential equation which is a governing equation of the moisture content of the soil for the one-dimensional unsteady flow in the unsaturated porous medium in a downward direction.

Since the moisture content  $\theta$  is increasing as depth  $z$  increasing for any  $t > 0$ , it is appropriate to choose initial moisture content as

$$\theta(z, 0) = 1 - e^{-z} \text{ (Singh et al., 2015)} \quad (\text{xi})$$

$$\text{Let } \frac{a}{b^3} (b + 2\theta) = G(\theta) \quad (\text{xii})$$

By the equation (x), we get

$$\begin{aligned} \frac{\partial G}{\partial t} &= \frac{\partial}{\partial z} \left( G \frac{\partial G}{\partial z} \right) + A \frac{\partial G}{\partial z} \\ \therefore \frac{\partial G}{\partial t} &= G \frac{\partial^2 G}{\partial z^2} + \left( \frac{\partial G}{\partial z} \right)^2 + A \frac{\partial G}{\partial z} \end{aligned} \quad (\text{xiii})$$

$$\text{where } A = \frac{\rho g}{\rho_s} \left( \frac{\lambda}{2b^2} - \gamma \right)$$

#### 4. SOLUTION OF THE PROBLEM BY SUCCESSIVE LINEARISATION METHOD (SLM)

Using similarity transformation (Parikh, Mehta and Pradhan, 2012),

$$G(z, t) = tf(\eta); \eta = \frac{z}{t} \quad (\text{xiv})$$

By the equation (xiii), we get

$$f(\eta)f''(\eta) + (\eta + A)f'(\eta) + (f'(\eta))^2 - f(\eta) = 0 \quad (\text{xv})$$

$$\text{where } f(0) = 0; z = 0, t > 0 \text{ and } f(\infty) = 1; t = 0, z > 0 \quad (\text{xvi})$$

To use SLM (Motsa et al., 2011), consider a solution of the equation (xv) as

$$f = f_i + \sum_{m=0}^{i-1} f_m; i = 1, 2, 3, \dots \quad (\text{xvii})$$

Putting this value in the equation (xv) and neglecting nonlinear term in  $f_i$ , we get

$$\begin{aligned} \left( \sum_{m=0}^{i-1} f_m \right) f_i'' + \left( \eta + A + 2 \sum_{m=0}^{i-1} f_m' \right) f_i' \\ + \left( \sum_{m=0}^{i-1} f_m'' - 1 \right) f_i = \sum_{m=0}^{i-1} f_m \\ - \left[ (\eta + A) \sum_{m=0}^{i-1} f_m' + \left( \sum_{m=0}^{i-1} f_m \right) \left( \sum_{m=0}^{i-1} f_m'' \right) + \left( \sum_{m=0}^{i-1} f_m' \right)^2 \right] \end{aligned}$$

$$\text{Consider } a_{i-1} = \sum_{m=0}^{i-1} f_m, b_{i-1} = \eta + A + 2 \sum_{m=0}^{i-1} f_m', c_{i-1} = \sum_{m=0}^{i-1} f_m'' - 1 \quad (\text{xviii})$$

and

$$r_{i-1} = \sum_{m=0}^{i-1} f_m - \left[ (\eta + A) \sum_{m=0}^{i-1} f_m' + \left( \sum_{m=0}^{i-1} f_m \right) \left( \sum_{m=0}^{i-1} f_m'' \right) + \left( \sum_{m=0}^{i-1} f_m' \right)^2 \right] \quad (\text{xix})$$

$$\therefore a_{i-1}f_i'' + b_{i-1}f_i' + c_{i-1}f_i = r_{i-1} \quad (\text{xx})$$

$$\text{where } f_i(0) = 0 = f_i(1) \quad (\text{xxi})$$

$$\text{Choose } f_0(\eta) = 1 - e^{-\eta} \quad (\text{xxii})$$

which is feasible with the physical phenomenon.

By solving the equations (xx) iteratively, we get each solution for  $f_i (i \geq 1)$ , thus the approximate solution for  $f(\eta)$  is obtained as

$$f(\eta) \approx \sum_{m=0}^K f_m(\eta) \quad (\text{xxiii})$$

$$\text{which is obtained by assuming } \lim_{i \rightarrow \infty} f_i = 0 \quad (\text{xxiv})$$

Now  $a_{i-1}$ ,  $b_{i-1}$ ,  $c_{i-1}$  and  $r_{i-1}$  of the equation (xx) are known from the previous iterations for  $i = 1, 2, 3, \dots$ , so the equation can be solved using numerical methods easily.

Here we solved the equations (xx) using the Chebyshev spectral collocation method (Motsa et al., 2011).

To apply it, transform the physical region  $[0, 1]$  into  $[-1, 1]$  using the mapping

$$\eta = \frac{\xi+1}{2}; -1 \leq \xi \leq 1 \quad (\text{xxv})$$

Use the Gauss-Lobatto collocation points [15] to define the Chebyshev nodes in  $[-1, 1]$ , namely

$$\xi_j = \cos \frac{\pi j}{N}; j = 0, 1, 2, \dots, N \quad (\text{xxvi})$$

The variable  $f_i$  is approximated by the truncated Chebyshev series given by

$$f_i(\xi) = \sum_{k=0}^N f_i(\xi_k) T_k(\xi_j) \quad (\text{xxvii})$$

where  $T_k(\xi) = \cos[k \cos^{-1}(\xi)]$  is the  $k^{\text{th}}$  Chebyshev polynomial. Derivatives of the variables at the collocation points are given by

$$\frac{d^r f_i}{d\eta^r} = \sum_{k=0}^N D_{kj}^r f_i(\xi_k) \quad (\text{xxviii})$$

where  $D = 2\mathcal{D}$ , with  $\mathcal{D}$  is the Chebyshev spectral differentiation matrix, whose entries are defined as

$$\mathcal{D}_{jk} = \frac{c_j (-1)^{j+k}}{c_k \xi_j - \xi_k}; j \neq k; j, k = 0, 1, 2, \dots, N;$$

$$\mathcal{D}_{kk} = \frac{\xi_k}{2(1-\xi_k^2)}; k = 1, 2, \dots, N-1; \mathcal{D}_{00} = \frac{2N^2+1}{6} = -\mathcal{D}_{NN} \quad (\text{xxix})$$

Substituting values of the equations (xxvii) to (xxix) in the equation (xx), we get

$$A_{i-1} F_i = \Phi_{i-1} \quad (\text{xxx})$$

$$\text{subject to } f_i(\xi_N) = 0, \sum_{k=0}^N D_{Nk} f_i(\xi_k) = 0, f_i(\xi_0) = 0 \quad (\text{xxxi})$$

$$\text{where } A_{i-1} = a_{i-1} D^2 + b_{i-1} D + c_{i-1} \quad (\text{xxxii})$$

$$F_i = [f_i(\xi_0), f_i(\xi_1), \dots, f_i(\xi_N)]^T \quad (\text{xxxiii})$$

$$\Phi_{i-1} = [\phi_{i-1}(\xi_0), \phi_{i-1}(\xi_1), \dots, \phi_{i-1}(\xi_N)]^T \quad (\text{xxxiv})$$

Now applying the boundary conditions  $f_i(\xi_0) = 0$  and  $f_i(\xi_N) = 0$ , we obtained solutions for  $f_i(\xi_1), f_i(\xi_2), \dots, f_i(\xi_{N-1})$  iteratively from solving

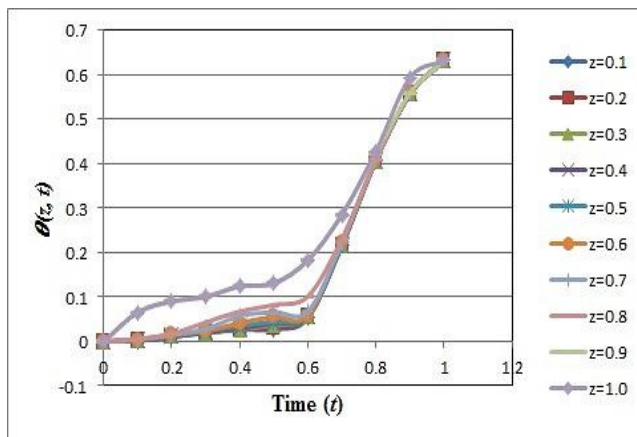
$$F_i = A_{i-1}^{-1} \Phi_{i-1} \quad (\text{xxxv})$$

## 5. NUMERICAL AND GRAPHICAL REPRESENTATION

From the solution (xxxv), we can find the moisture content of soil in the one-dimensional downward direction using MATLAB. Also, the numerical, as well as graphical representations of the solution (xxxv), have been discussed. Fig.2 represents the graph of moisture content  $\theta(z, t)$  versus time  $t$  for fixed depth  $z = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0$  and the following Table-I indicates their numerical values.

**TABLE I: Moisture Content  $\theta(z, t)$  for Different Depth  $z$  and Time  $t$**

t	Moisture content of the soil: $\theta(z, t)$									
	z=0.1	z=0.2	z=0.3	z=0.4	z=0.5	z=0.6	z=0.7	z=0.8	z=0.9	z=1.0
0.1	0.000999	0.001605	0.001871	0.002849	0.002981	0.004228	0.004409	0.005463	0.065689	0.065698
0.2	0.010313	0.010358	0.012242	0.012284	0.012696	0.015206	0.015284	0.017305	0.09019	0.090197
0.3	0.018992	0.020326	0.020643	0.021713	0.022979	0.023971	0.028225	0.043071	0.10056	0.100615
0.4	0.02628	0.027415	0.027428	0.028985	0.036127	0.04167	0.05776	0.06744	0.124369	0.124388
0.5	0.027394	0.031356	0.037496	0.040708	0.045119	0.05578	0.066092	0.082217	0.130721	0.130727
0.6	0.052589	0.057239	0.057252	0.057469	0.05869	0.0588	0.067473	0.101564	0.182857	0.182915
0.7	0.216666	0.216686	0.216700	0.216804	0.217726	0.222926	0.222947	0.231347	0.285400	0.285718
0.8	0.407373	0.4074	0.407448	0.40751	0.407521	0.408441	0.408522	0.409549	0.424164	0.428007
0.9	0.557039	0.557096	0.557117	0.557178	0.557213	0.557438	0.558041	0.558746	0.559506	0.593582
1.0	0.632121	0.632121	0.632121	0.632121	0.632121	0.632121	0.632121	0.632121	0.632121	0.632121



**Fig. 2. Moisture content  $\theta(z, t)$  versus time  $t$  with fixed depth  $z$**

## 6. CONCLUSION

From the solution (xxxv), we have found the moisture content of the soil for any depth  $z$  and for any time  $t > 0$  by using MATLAB. By Table-I, we can say that the moisture content of the soil is increasing as depth  $z$  is increasing for any time  $t > 0$ . Figure-2 shows the moisture at different time  $t$  when depth  $z$  is fixed, which is feasible with the physical fact. So SLM gives an effective result for the Fokker-Planck equation of a vertical groundwater recharge in unsaturated porous media.

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# A Hybrid Fuzzy AHP- ELECTRE Approach to Rank Lean Six Sigma Solutions: Case Experience of a Manufacturing Organisation

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**Abstract:** Quick product variations and burden of worldwide rivalry demands to keep up the envisioned product quality at least conceivable expense to hold their current clients and in addition draw in the new ones. This changing industrial scenario engenders a strong need to adopt a hybrid approach that could tackle their application issues. Lean Six Sigma (LSS) has emerged as a prime choice for industries to sustain in global market during the last decade. While, in order to implement LSS effectively it is extremely significant to identify the key LSS barriers as well as solution approaches to tackle them. The present study identifies 14 key LSS barriers and 12 solution approaches through literature review and opinion from industry experts. The present study proposes a hybrid framework of fuzzy AHP-ELECTRE to prioritize LSS barriers and LSS solution approaches. Inclusion of fuzzy sets in the hybrid framework ensures the optimality of results. The developed framework is applied to an Indian manufacturing organization to judge its applicability whereas; sensitivity analysis is applied to check the robustness of the developed framework. The findings of this study will help the industry practitioners to handle the LSS implementation issues and the researchers to explore the new directions in the domain of LSS.

**Keywords:** “lean six sigma, barriers, solution approaches, hybrid approach, fuzzy AHP, ELECTRE”

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## 1. INTRODUCTION

The question of how to meet the challenge of quality standard and removal of non-value added activities has concerned researchers and industry practitioners ever since couple of decades (Yadav and Desai, 2016). In the last decade, quality improvement has been characterized by two major approaches: Lean development, which aims to tackle process efficiency by eliminating non-value-adding steps and activities in a process, and Six Sigma, which inhibits the process variation on priority by imparting the entire process towards mean. Hybrid development of the two practices is their fusion, which is termed as Lean Six Sigma (LSS). While understanding the requirement to deliver business value to the consumer in a rapidly changing environment and considering the demands of end-users into account, the integration of Lean development and Six Sigma seems to be a promising endeavour and has received increasing attention in recent years. Various authors (Drohomeretski et al., 2014; Karthi et al., 2011; Salah et al., 2010) proposed to combine the merits of both approaches in order to design an expertise quality improvement tool. The modern view of quality development prevalent in earlier phase-based basic approaches has been replaced by number of statistical tools and innovative techniques. This excogitated to sporadic change by noticing drastic improvement in processes leading towards growth of entire organizational productivity which later adds the business value for the customer.

In order to implement any productive tool or methodology in the organization, prelude measure includes its precise visualisation. Therefore, congruous research output makes critical literature reviews as essential instrument for evaluating and building up the knowledge base within a research domain. Replicability of the research as well as attributes of the arguments and conclusions, call for more crystal clear and systematic procedures. To the cognition of the authors, no such study is conducted earlier which critically review the research articles in LSS and categorized them over the multiple parameters. Hence there is a need of categorized review which reflects the present scenario, mentioning the developments of LSS. The objective of this paper is to expatiate on elucidating egressing vistas, trends and importance of LSS through reviewing the published literature over multiple parameters for better understanding of the research domain.

## 2. LITERATURE REVIEW

### 2.1 LSS solution approaches

Core strengths of Lean Six Sigma provide manufacturing flexibility in variety of operations. Proper implementation of Lean Six Sigma leads to stand and build the organizations branding in the global market. As competition level to sustain in the market is very high, so the organization needs to check continuously towards quality

improvement methods as they provide them a base to withstand in changing market variety.

Lean Six Sigma also focuses customer satisfaction which includes on time delivery, better quality, after sales support which helps in retaining the customer from moving towards other brands. With adequate planning of processes, the manufacturing costs can easily bring down to increase the market profit. As the complete process moves from top to bottom and includes brainstorming sessions, weekly meetings and suggestions from subordinates, it breaks the functional barriers within the organization and let innovative ideas to get absorb within the organizations policies.

The mapping of process is one of the important aspects of any manufacturing organization. It leads to proper utilization of space and equipment which is done through value stream mapping. The bottle necks, waiting time, idle time etc. are easily mapped with it and corrective measures are done. It helps in making on time deliveries to hold the existing customers and increase the business performance.

Lean Six Sigma sets up a complete organized structure of the organization by linking up all the process and creating a healthy environment for the employees which helps in improving employee efficiency. Any flaws occurred in the stream can be detected and fixed within short span of time. Table 1 describes the LSS solutions extracted through literature.

**TABLE 1: LSS solutions extracted through literature review**

S.N.	Solutions of LSS	Literature Support
1	Increase in manufacturing flexibility	(Albliwi et al., 2015; Hilton and Sohal, 2012; Prasanna and Vinodh, 2013)
2	Better standing against global competition	(Jadhav et al., 2014), (Kumar and Antony, 2008; Pinedo-Cuenca et al., 2012; Prasanna and Vinodh, 2013)
3	Increase in quality	(Hu et al., 2015; Jadhav et al., 2014; Maleyeff, 2012)
4	Better customer satisfaction	(Hilton and Sohal, 2012; Manville et al., 2012)
5	Reduction in manufacturing costs	(Yadav and Desai, 2016), (Hilton and Sohal, 2012)
6	Breakdown of functional barriers within the company	(Maleyeff, 2012; Pinedo-Cuenca et al., 2012; Prasanna and Vinodh, 2013)
7	Better utilization of space and equipment	(Assarlind and Aaboen, 2013; Hu et al., 2015; Kumar and Antony, 2008)
8	Higher employee efficiency	(Jadhav et al., 2014; Pinedo-Cuenca et al., 2012)
9	Increase in business performance	(Hu et al., 2015; Jadhav et al., 2014; Pinedo-Cuenca et al., 2012)
10	Improved on time deliveries	(Jadhav et al., 2014; Kumar and Antony, 2008; Pinedo-Cuenca et al., 2012)
11	Increase in employee suggestions	(Hu et al., 2015; Jadhav et al., 2014; Thomas et al., 2009)
12	Increase in manufacturing flexibility	(Yadav and Desai, 2016), (Albliwi et al., 2015)

## 2.2 LSS barriers

The challenges to implement Lean Six Sigma are observed in sectors- manufacturing, service, government, healthcare etc. Therefore, it is crucial for all the organizations to identify and excrete them for acquiring operational excellence. Critical challenging factors in context of manufacturing are discussed below. Table 2 describes the LSS barriers reported in literature.

**TABLE 2: LSS barriers extracted through literature review**

S.N.	Barriers of LSS	Literature Support
1	Deficient top management commitment	(Hu et al., 2015; Jadhav et al., 2014; Pinedo-Cuenca et al., 2012)
2	Deficient cognizance of quality at management level	(Maleyeff, 2012; Pinedo-Cuenca et al., 2012; Prasanna and Vinodh, 2013)
3	Deficient continuous training and education	(Assarlind and Aaboen, 2013; Hu et al., 2015; Kumar and Antony, 2008)
4	Inability to modify organisational culture	(Albliwi et al., 2015; Hilton and Sohal, 2012; Prasanna and

S.N.	Barriers of LSS	Literature Support
		Vinodh, 2013)
5	Ineffective evaluation methods and lack of access to data and results	(Hu et al., 2015; Jadhav et al., 2014; Thomas et al., 2009)
6	Uncongenial organisation structure and isolated individuals and departments	(Yadav and Desai, 2016), (Albliwi et al., 2015), (Hilton and Sohal, 2012)
7	Inadequate attention to internal and external customers	(Jadhav et al., 2014), (Kumar and Antony, 2008; Pinedo-Cuenca et al., 2012; Prasanna and Vinodh, 2013)
8	Inappropriate reward and recognition system	[11],
9	Lack of cost and benefit analysis	(Jadhav et al., 2014; Pinedo-Cuenca et al., 2012)
10	Inability to build a learning organisation that provides continuous improvement	(Hu et al., 2015; Jadhav et al., 2014; Maleyeff, 2012)
11	Accounting systems	(Yadav and Desai, 2016), (Hilton and Sohal, 2012)
12	Unconventional planning and deficient resources,	(Jadhav et al., 2014; Kumar and Antony, 2008; Pinedo-Cuenca et al., 2012)

### 2.3 Multi criteria decision making methods

MCDM is a kind of hybrid evaluation system. It helps in evaluating shop floor activities and deciding the best strategies and methodology to be adopted for handling hybrid problems with multi constraints, complex scenarios, different objectives, varied kind of process data and inputs, multi interests and biasness, and the capturing for composite and developing several socio-economic systems. The available methods aids in exploring the solutions to enhance the positive view towards complex industrial environment issues. A stand alone attribute approach basically focuses at keying out the most optimum alternative at a minimum cost. Growing global competition in the 1990s has entirely modified the standalone framework to a hybrid framework. Presently, the concentration on global industrial competition issues drives MCDM delve into hybrid methods. The MCDM methods have been widely applied to social, economic, agricultural, industrial, ecological and biological systems in addition to energy systems. Compared to single criteria approach, the distinctive advantage of MCDA methods is to employ multi-criteria or attributes to obtain an integrated DM result. Generally, the MCDA problem for sustainable energy DM involves  $m$  alternatives evaluated on  $n$  criteria. The grouped decision matrix can be expressed as follows:

$$\begin{array}{c}
 \text{criteria } C_1 \quad C_2 \quad \cdots \quad C_n \\
 \text{(weights } w_1 \quad w_2 \quad \cdots \quad w_n) \\
 \text{alternatives } \text{---} \text{---} \text{---} \text{---} \text{---} \text{---} \\
 \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array}
 \end{array}
 \begin{pmatrix}
 x_{11} & x_{12} & \cdots & x_{1n} \\
 x_{21} & x_{22} & \cdots & x_{2n} \\
 \vdots & \vdots & \ddots & \vdots \\
 x_{m1} & x_{m2} & \cdots & x_{mn}
 \end{pmatrix}_{m \times n}$$

where  $x_{ij}$  is the performance of  $j$ -th criteria of  $i$ -th alternative,  $w_j$  is the weight of criteria  $j$ ,  $n$  is the number of criteria and  $m$  is the number of alternatives (these nomenclatures are just the same in this article).

It is well known that every decision making problem comprises of alternative, criteria, criteria weights and the evaluating result. At the initial stage it is significant to construct a decision hierarchy that could align the entire decision problem. This is basically carried out in four phases: alternatives' formulation and criteria selection, criteria weighting, evaluation, and final treatment and aggregation (Yadav and Desai, 2017a). This is the initial phase to formulate the alternatives for LSS solutions, from a set of selected criteria and to normalize the original data of criteria. Secondly, criteria weights are determined to show the relative importance of criteria in MCDA. Then, the acceptable alternatives are ranked by MCDA methods with criteria weights. Finally, the alternatives' ranking is ordered. If all alternatives' ranking orders in different MCDA methods are just the same, the DM process is ended. Otherwise, the ranking results are aggregated again and the best scheme is selected. In this concern a hybrid fuzzy AHP-ELECTRE method is adopted.

### 3. CASE APPLICATION

The hybrid framework is applied to a manufacturing organisation ABC which primarily deals in the production of electronic switches and appliances. The ABC firm encountered the issues related to wastes and quality which resulted in huge lot rejection. This dual issue directly affected their market capital and reduced the number of existing customers. Hence, the managers of the firm conducted several meetings and came forward with a conclusion to adopt a hybrid methodology that could overcome the confronted dual issues. To facilitate the LSS



implementation the authors suggested the ABC management to apply the developed framework in their organization to overcome implementation issues. The framework works in two parts; firstly. Fuzzy AHP helps in finding the weights of criteria whereas ELECTRE helps in ranking the solutions.

### 3.1 Fuzzy AHP

As a practical yet popular methodology for dealing with fuzziness and uncertainty in multiple criteria decision-making(MCDM), fuzzy analytic hierarchy process (AHP) has found huge applications in recent years(Kaya and Kahraman, 2010). Since fuzzy judgments are easier to provide than crisp judgments, it can be concluded that fuzzy AHP will find more applications in the near future(Yadav and Desai, 2017b). The use of fuzzy AHP for multiple criteria decision-making requires scientific approaches for deriving the weights from fuzzy pairwise comparison matrices(He et al., 2012). Existing approaches for fuzzy AHP weight derivation can be classified into two categories, one of which is to derive a set of fuzzy weights from a fuzzy pairwise comparison matrix, while the other is to derive a set of crisp weights from a fuzzy pairwise comparison matrix(Huang et al., 2009). The approaches for deriving fuzzy weights from fuzzy pairwise comparison

matrices mainly include the geometric mean method, fuzzy logarithmic least-squares methods (LLSM), Lambda–Max methods and the linear goal programming (LGP) method(Prakash and Barua, 2015). The approaches for deriving crisp weights from fuzzy pairwise comparison matrices include the extent analysis and the fuzzy preference programming (FPP) based nonlinear method(Aydin and Kahraman, 2010).

**TABLE 3: Fuzzy evaluation scores**

Linguistic value	Fuzzy value
Extremely high influence	2,2.5,3
Very high influence	1.5,2,2.5
Fairly high influence	1,1.5,2
Slightly high influence	1,1,1.5
Equal	1,1,1
Slightly low influence	2/3,1,1
Fairly low influence	0.5,2/3,1
Very low influence	0.4,0.5,2/3
Extremely low influence	1/3,0.4,0.5

**TABLE 4: Fuzzy comparison of LSS criteria barriers**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.9	1.0
C2	0.4	1.0	0.7	0.4	0.8	1.0	0.3	0.3	0.0	0.2	0.9
C3	0.7	1.0	1.0	0.7	1.0	1.0	0.6	0.6	0.4	0.6	1.0
C4	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.6	0.8	1.0
C5	0.5	1.0	0.9	0.6	1.0	1.0	0.5	0.4	0.2	0.4	1.0
C6	0.4	1.0	0.7	0.4	0.8	1.0	0.3	0.1	0.1	0.3	1.0
C7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.7	0.9	1.0
C8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0
C9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
C10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0
C11	0.5	1.0	0.8	0.5	0.9	1.0	0.4	0.4	0.1	0.3	1.0

Analytical Hierarchy Process (AHP), introduced by Thomas L. Saaty, is one of the most efficient decision making techniques(Percin and Kahraman, 2010). The comparison matrix of AHP divides a problem into sub-problems which is much easier to solved, it has been considered as useful way of criteria weighting determination(Yadav and Desai, 2017c). Considering the uncertain judgments of decision-makers, fuzzy AHP with linguistic pair-wise comparisons is more rational than crisp ones(Yadav et al., 2017). Moreover, Hilton and Sohalpropose the extent analysis to improve the

conventional fuzzy AHP with Logarithmic least squares (LLS), which is much better at time complexity. Therefore, in this study, the fuzzy AHP with extent analysis will be employed to determine the subjective weights. For the fuzzy AHP with triangular fuzzy numbers (TFNs) (in Table 3).Check the consistency of comparison matrix In order to check the consistency of the comparison matrix, the consistency ratio (CR) should be computed after the defuzzification of triangular fuzzy numbers matrix. In this paper, the graded mean integration approach is employed to transform a triangular fuzzy number (He et al., 2012).

**TABLE 5: Final weights of criteria barriers**

Criteria	Ratio Wt.	Final Wt.	Rank
C1	0.23639	0.10631	3
C2	0.06343	0.02852	7
C3	0.15989	0.07190	4
C4	0.03443	0.01548	9
C5	0.37585	0.26903	1
C6	0.02045	0.0092	11
C7	0.10951	0.04925	5
C8	0.03871	0.01106	10
C9	0.52216	0.14923	2
C10	0.06977	0.01994	8
C11	0.11190	0.03198	6

### 3.2 ELECTRE

Electre method was developed by Bernard Roy to solve several multi criteria decision making issues observed during managerial decisions (Khanna et al., 2011). It helps in doing the paired comparison of each alternative with respect to each attribute considered. It also provides flexibility to the decision maker to consider to make fair judgements.

The paired comparison of attributes and alternatives is presented in Table 6.

**TABLE 6: Paired comparison of criteria and alternatives**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0.8	0.9	0.7	0.9	0.5	0.9	0.5	0.9	0.7	0.9	0.9
A2	0.5	0.9	0.5	0.9	0.3	0.7	0.5	0.9	0.5	0.7	0.9
A3	0.9	0.9	0.7	0.9	0.7	0.9	0.7	0.9	0.9	0.9	0.9
A4	0.3	0.7	0.3	0.9	0.1	0.7	0.1	0.9	0.3	0.5	0.9
A5	0.3	0.9	0.3	0.9	0.1	0.7	0.1	0.9	0.3	0.5	0.9
A6	0.9	0.9	0.7	0.9	0.5	0.9	0.7	0.9	0.9	0.9	0.9
A7	0.3	0.7	0.3	0.9	0.1	0.7	0.1	0.9	0.3	0.5	0.9
A8	0.9	0.9	0.7	0.9	0.5	0.9	0.7	0.9	0.7	0.9	0.9
A9	0.1	0.7	0.1	0.9	0.1	0.5	0.1	0.9	0.1	0.3	0.7
A10	0.7	0.9	0.5	0.9	0.3	0.9	0.5	0.9	0.5	0.7	0.9
A11	0.3	0.7	0.1	0.9	0.1	0.5	0.1	0.9	0.1	0.3	0.7
A12	0.5	0.9	0.3	0.9	0.3	0.7	0.3	0.9	0.5	0.5	0.9

The above matrix compares the 12 identified alternatives of the present problem among the different available criterias. With the help of Table 6 the concordance matrix is developed.

**TABLE 7: Concordance matrix**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	1	0.8	0.7	0.9	0.7	0.9	0.5	0.9	0.7	0.9	0.9
A2	0.5	1	0.4	0.8	0.4	0.7	0.5	0.9	0.5	0.7	0.9
A3	0.7	0.6	1	0.6	0.7	0.9	0.7	0.9	0.9	0.9	0.9
A4	0.8	0.9	0.5	1	0.4	0.7	0.1	0.9	0.3	0.5	0.9
A5	1	0.8	1	0.9	1	0.7	0.1	0.9	0.3	0.5	0.9
A6	0.9	0.9	0.7	0.9	0.5	1	0.8	0.7	0.9	0.7	0.9
A7	0.3	0.7	0.3	0.9	0.1	0.5	1	0.4	0.8	0.4	0.9
A8	0.9	0.9	0.7	0.9	0.5	0.7	0.6	1	0.6	0.7	0.9
A9	0.1	0.7	0.1	0.9	0.1	0.8	0.9	0.5	1	0.4	0.7
A10	0.7	0.9	0.5	0.9	0.3	1	0.8	1	0.9	1	0.9
A11	0.3	0.7	0.1	0.9	0.1	0.5	0.1	0.9	0.1	0.3	1
A12	0.5	0.9	0.3	0.9	0.3	0.7	0.3	0.9	0.5	0.5	0.9

**TABLE 8: Discordance matrix**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0	0.5	0.6	0.6	0.8	0.7	0.6	0.6	0.5	0.7	0.8
A2	0.4	0	0.4	0.8	0.4	0.7	0.5	0.9	0.5	0.7	0.9
A3	0.6	0.6	0	0.6	0.7	0.9	0.7	0.9	0.9	0.9	0.9
A4	0.4	0.9	0.5	0	0.4	0.7	0.1	0.9	0.3	0.5	0.9
A5	0	0.8	0	0.9	0	0.7	0.1	0.9	0.3	0.5	0.9
A6	0.9	0.9	0.7	0.9	0.5	0	0.8	0.7	0.9	0.7	0.9
A7	0.3	0.7	0.3	0.9	0.1	0.5	0	0.4	0.8	0.4	0.9
A8	0.9	0.9	0.7	0.9	0.5	0.7	0.6	0	0.6	0.7	0.9
A9	0.1	0.7	0.1	0.9	0.1	0.8	0.9	0.5	0	0.4	0.7
A10	0.7	0.9	0.5	0.9	0.3	0	0.8	0	0.9	0	0.9
A11	0.3	0.7	0.1	0.9	0.1	0.5	0.1	0.9	0.1	0.3	0
A12	0.5	0.9	0.3	0.9	0.3	0.7	0.3	0.9	0.5	0.5	0.9

**TABLE 9: Superiority matrix**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0	0.5	0.6	0.6	0.8	0.7	0.6	0.6	0.5	0.7	0.8
A2	0.4	0	0.4	0.8	0.4	0.7	0.5	0.9	0.5	0.7	0.9
A3	0.6	0.6	0	0.6	0.7	0.9	0.7	0.9	0.9	0.9	0.9
A4	0.4	0.9	0.5	0	0.4	0.7	0.1	0.9	0.3	0.5	0.9
A5	0	0.8	0	0.9	0	0.7	0.1	0.9	0.3	0.5	0.9

<b>A6</b>	0.9	0.9	0.7	0.9	0.5	0	0.8	0.7	0.9	0.7	0.9
<b>A7</b>	0.3	0.7	0.3	0.9	0.1	0.5	0	0.4	0.8	0.4	0.9
<b>A8</b>	0.9	0.9	0.7	0.9	0.5	0.7	0.6	0	0.6	0.7	0.9
<b>A9</b>	0.1	0.7	0.1	0.9	0.1	0.8	0.9	0.5	0	0.4	0.7
<b>A10</b>	0.7	0.9	0.5	0.9	0.3	0	0.8	0	0.9	0	0.9
<b>A11</b>	0.3	0.7	0.1	0.9	0.1	0.5	0.1	0.9	0.1	0.3	0
<b>A12</b>	0.5	0.9	0.3	0.9	0.3	0.7	0.3	0.9	0.5	0.5	0.9

**TABLE 10: Final ranking of alternatives**

<b>Alt.</b>	<b>Concord. Credibility</b>	<b>Discord. Credibility</b>	<b>Sup. ratio</b>	<b>Rank</b>
A1	4.3497	4.0676	1.0693	5
A2	2.7095	4.0411	0.6704	11
A3	3.3717	3.5913	0.9388	6
A4	3.8677	4.3831	0.8823	7
A5	4.8116	3.0267	1.589	1
A6	3.2784	4.0676	0.7851	8
A7	3.7571	4.0411	0.6852	10
A8	3.9462	3.5913	1.2584	3
A9	2.4353	4.3831	0.5825	12
A10	2.7567	3.0267	0.6952	9
A11	3.5418	3.0267	1.3564	2
A12	4.2183	4.0676	1.2342	4

The discordance matrix represented in table 8 describes the variations in influence of any respective alternative with the corresponding criteria. It also helps in enhancing the precision of the decision maker towards their final judgements(Mousavi et al., 2017). Table 9 represents the superiority matrix that final describes the relationship among the influence criteria towards selection of alternatives. Finally, Table 10 portrays the final ranking of the alternatives.

#### 4. DISCUSSION AND CONCLUSION

It can be clearly observed that the developed hybrid framework allows the decision maker to make the rankings of the alternatives solutions of LSS to overcome the selected set of LSS barriers. The literature review conducted in the initial phase of the study shows that many manufacturing industries across the world have observed the LSS implementation failures, hence it becomes extremely significant to identify the set of LSS barriers on the selected industry domain as well as the solutions that helps to overcome the barriers. In the present study a hybrid fuzzy AHP-ELECTRE approach is employed to rank the

solutions that can overcome the LSS barriers. The developed framework is applied to an electronics and electrical appliance manufacturing organisation which was struggling to withstand in the global competition. By applying this framework in the case organization, the final ranking of LSS solutions is obtained. The present study will be beneficial for researchers and industry practitioners. As industry practitioners can apply this hybrid framework to their respective domain in order to obtain the implementation benefits and tackle the implementation issues. While, the researchers can find the different applications of the framework and can modify the present version of the framework by including grey relational analysis to increase the framework applicability. In spite of several benefits rendered, the present study possesses several limitations. The set of LSS barriers and solution approaches are shortlisted for manufacturing environment. The shortlisted set is small hence the researchers can increase the set of barriers and solutions to improve feasibility of the study. A large scale survey can be conducted to justify the included set of LSS barriers as well as solutions. The outcomes of the present study will be extremely beneficial for the researchers as well as

practitioners; while this study will also open new research threads in the domain of LSS. The international readers will also gain benefit by this study as they can utilise this study as a base for conducting manufacturing industry case experience in different countries.

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# Optimization of Drilling Process Parameters Using Advanced Optimization Algorithms

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**Abstract** - The machining process parameters has its impact on the quality of the components produced. To achieve the customer demands and survival in the competitive market, need of the optimization of process parameters has become essential. In the present work, selected advanced optimization techniques like jaya algorithm and teaching and learning based optimization are implemented to optimized the drilling process parameters like speed, feed and point angle. These algorithms required minimum number of iterations to optimize the process parameters as compared to other algorithms. The results of selected algorithms for material removal rate are compared with the values obtained from response surface methodology and it is observed that the selected optimization techniques gives better solution than the response surface methodology.

**Keywords**- Drilling process, material removal rate, jaya algorithm, teaching and learning based optimization.

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## 1. INTRODUCTION

The rapid advancement in the machining processes increases the efficiency and gives better results of available resources by its effective utilization. The costing of the process largely depends upon the input process parameters which in turns has impact on the quality of the required product. Drilling facilitates assembly of composite parts and derives better machining rate with an improved surface finish. The quality of the components produced is influenced by various parameters like speed, feed and point angle, etc. Therefore, it is essential to optimized the machining parameters to get the optimum results. In the present work, selected advanced optimization techniques like jaya algorithm and teaching and learning based optimization (TLBO) are implemented on a case study in which optimization of the drilling process parameters like speed, feed and point angle with material removal rate (MRR) as a response parameter are considered. The response surface methodology (RSM) is used for the optimization purpose in the case study but the selected techniques are easy for the implementation as these are based on simple phenomenon like teaching-learning process for TLBO and random number philosophy for Jaya algorithm.

The TLBO algorithm based on teacher and learner phenomenon. This algorithm is superior than other algorithms in aspect of both time for optimization and number of iterations required. It also adoptable for variety of application independent upon number of parameters, single or multi-objective solutions, constrained or unconstrained problems. Also, Jaya algorithm is predicated on the idea that the outcome obtained for a given problem should move towards the best solution and evade the worst solution. This evolutionary approach does not require any

particular algorithm specific control parameter, rather mandates common control parameters.

## 2. LITERATURE REVIEW

Several researchers worked on optimization of process parameters of various engineering problems using optimization techniques like Genetic algorithm (GA), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC) and Harmony Search (HS) etc. But the main limitation of all the algorithms mentioned is that different parameters are required for proper working of these algorithms. GA provides a near optimal solution for a complex problem having large number of variables and constraints. This is mainly due to the difficulty in determining the optimum controlling parameters such as population size, crossover rate and mutation rate. The same is the case with PSO, which uses inertia weight, social and cognitive parameters. Similarly, ABC requires optimum controlling parameters of number of bees (employed, scout, and onlookers), limit, etc. HS requires harmony memory consideration rate, pitch adjusting rate, and the number of improvisations. To overcome these mentioned limitations, in the present work, advanced optimization techniques like TLBO (investigated in 2011) and Jaya algorithm (investigated in 2016) are selected.

Togan (2012) proposed modified teaching learning based optimization techniques to design planner steel frames. The TLBO techniques effectiveness and robustness were demonstrated by optimal design of steel frames. The results of TLBO were compared with those GA, ACO, HS and improved ACO and concluded as TLBO is power search and applicable optimization for the engineering design problem. Rao and Patel (2013) implemented TLBO for multi objective optimization of two stage thermoelectric

cooler. Two different arrangements of thermoelectric coolers were considered for optimization. The cooling capacity and coefficient of performance were taken as objective function which has to maximize. The example was presented to depict accuracy and effectiveness of proposed algorithm. The performance of modified TLBO was validated by comparison between results of modified TLBO and GA, PSO and basic TLBO. Rao and Kalyankar (2016) depicted newly modified TLBO algorithm for advanced manufacturing processes namely ECM (Electrochemical Machining) and ECDM (Electrochemical Discharge Machining). They optimized these process parameters and compared results with ABC algorithm and proved that TLBO gives more optimum solutions. Yildiz A. R. (2012) proposed a novel hybrid optimization problem by using TLBO and taguchi method. This techniques were applied to two case studies of multi pass turning operation to demonstrate effectiveness of TLBO. The results obtained were compared with PSO, hybrid GA, integration of SA and Hooke-Jeeves pattern search, scatter search algorithm. Pawar and Rao (2012) depicted significance of selection of process variable in aspect of minimum machining cost and increased productivity. The optimization of grinding, abrasive water jet machining and turning processes were optimized by implementing TLBO algorithm. The performance was evaluated by comparing results of proposed algorithm with GA, SA, PSO, HS and ABC algorithm and shown TLBO gives better results.

Hoseini et. al. (2012) proposed modified TLBO to optimize optimal location of AVR's in distribution systems at the presence of distributed generators. Energy generation costs, electrical energy losses and voltage deviations were considered as objective functions. Multi objective optimization was done and results were validated by means of comparison between proposed algorithm and GA, PSO. Wang et al. (2013) surveyed the running mechanism of TLBO for dealing with the real-parameter optimization problems, and finally group its real world applications with a categorizing framework based on the clustering, multi-objective optimization, parameter optimization and structure optimization. Kurada and Kanadam (2016) attempted to solve an automatic clustering problem by optimizing multiple objectives such as automatic k-determination and a set of cluster validity indices concurrently using Jaya Algorithm. Kumar (2016) carried out design optimization of rolling element bearing by taking maximization of dynamic capacity as objective using Jaya algorithm and their results were compared with the results obtained from genetic algorithm. It is found that the results obtained using Jaya algorithm were much better than the other algorithm. Phulambrikar (2016) applied evolutionary methods like Bare-Bone Particle swarm optimization, Teaching Learning based and Jaya optimization algorithms to find out solution of economic load dispatch problem and their results are compared.

It is found from literature that Jaya algorithm and TLBO algorithm are applied over various engineering applications like optimal design of steel frames, optimization of two stage thermoelectric cooler, process parameter optimization of ECM and ECDM, multi pass turning operation, finding out optimal location of AVR's in distribution systems at the presence of distributed generators, solving automatic clustering problem, design optimization of rolling element bearing and also finding out the solution of economic load dispatch problem. Also, the results obtained through these techniques gives the optimized value of desired engineering problems with minimum time and less number of iterations than others algorithms.

### 3. ADVANCED OPTIMIZATION ALGORITHMS

#### 3.1 Teaching Learning Based Optimization

Rao et al. (2011) proposed an efficient optimization method TLBO for the optimization of mechanical design problems which works on the effect of influence of a teacher on learners. This algorithm is applied for wide range of applications independent of number of parameters, single objective or multi objective problems, etc. The parameters are optimized in two phases i.e. teacher phase and learner phase. As teacher's knowledge influences the outcome of the teaching process, hence best teacher can enhance the performance of whole class of the students. The student's phase consists of increment of understanding amongst students by means of mutual interaction, group studies and discussions. The highly optimized parameters results in better performance and enhanced outcome of processes. The basic procedure for consists following three stages:

i. Initialization: It define all the process parameters with deciding population size and number of iteration. It initiates the algorithm for further processing in teacher phase. The population ( $X$ ) is randomly initialized in a search space bounded by matrix consists of number of learner in class ( $N$ ) in rows and number of courses ( $D$ ) in columns. The  $j$ th parameter of the  $i$ th learner is assigned values randomly using the equation:

$$x_{(i,j)} = x_j^{\min} + \text{rand} * (x_j^{\max} - x_j^{\min})$$

where 'rand' represents a uniformly distributed random variable within the range (0, 1),  $x_j^{\min}$  and  $x_j^{\max}$  represent the minimum and maximum value for  $j$ th parameter. The parameters of  $i$ th learner for the generation 'g' are given as:

$$X_{(i)}^g = [x_{(i,1)}^g, x_{(i,2)}^g, x_{(i,3)}^g, \dots, x_{(i,j)}^g, \dots, x_{(i,D)}^g]$$

ii. Teacher Phase: The teacher phase include influence of teacher's knowledge on outcome of students hence in this phase optimized response parameters deciding initially and further optimization takes place in next phase.

$X_{\text{new},i} = X_{\text{old},i} + r_{j,i}(X_{j,\text{best},i} - T_p M_{j,i})$ , where  $M_{j,i}$  is the mean result of learner.



iii. Learner Phase: The process of mutual interaction tends to increase the knowledge of the learner. The parameter of the matrix  $X_{new}$  in the learner phase is given as:

For  $i = 1 : P_n$

Randomly select two learners  $X_i$  and  $X_j$ , where  $i \neq j$

If  $f(X_i) < f(X_j)$  ;  $X_{new,i} = X_{old,i} + r_i(X_i - X_j)$

$$X_{new}(i) = \begin{cases} X_g(i) + \text{rand}*(X_g(i) - X_g(r)) & \text{if } (X_g(i) > f(X_g(r))) \\ X_g(i) + \text{rand}*(X_g(r) - X_g(i)) & \end{cases}$$

The flowchart of TLBO algorithm is given in Fig. 1. Also, the concept of TLBO algorithm is further elaborated in the following pseudo code.

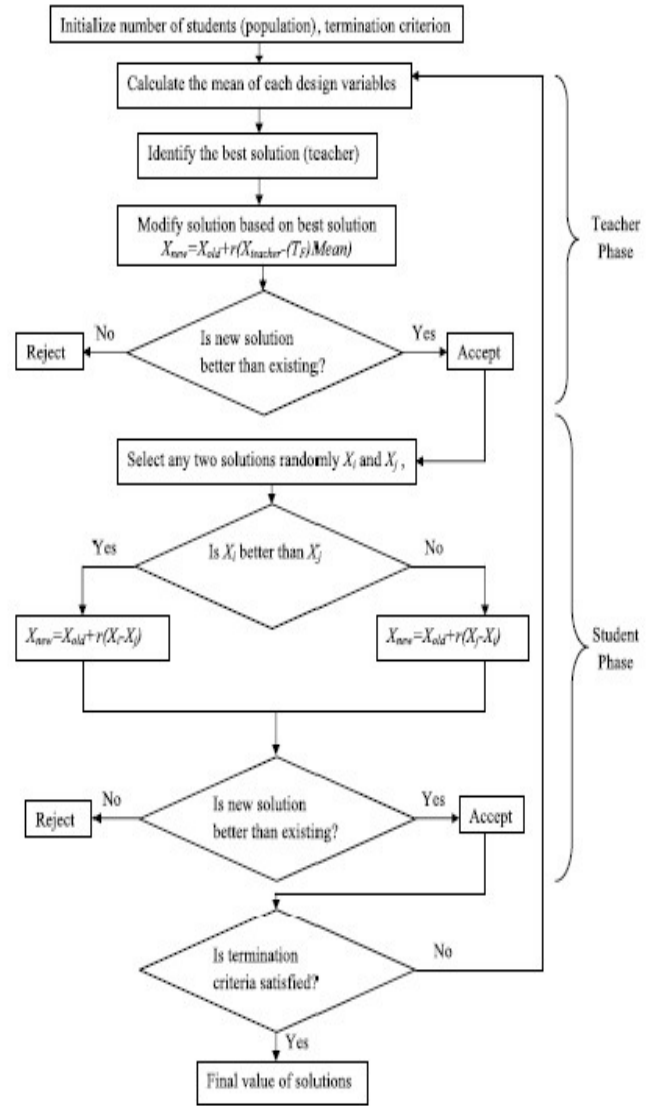
*Pseudo code*

- Set  $k = 1$  and generate initial students of the classroom randomly
- Define objective function,  $f(X) = f(x_1, x_2, \dots, x_D)$
- Calculate objective function  $f(X)$  for whole students of the classroom
- While (termination conditions are not met)
  - {Teacher Phase}
    - Calculate the mean of each design variable and identify the best solution (teacher)
  - For  $i = 1 \rightarrow n$ 
    - Calculate teaching factor  $TF_i = \text{round}[1 + \text{rand}(0,1)\{2-1\}]$
    - Modify solution based on best solution (teacher)  $X_{inew} = X_i + \text{rand}(0,1)[X_{teacher} - (TF_i * X_{mean})]$
    - Calculate objective function for new mapped student  $f(X_{inew})$
    - If  $X_{inew}$  is better than  $X_i$ , i.e.  $f(X_{inew}) < f(X_i)$   $X_i = X_{inew}$
  - End if {End of Teacher Phase}
- {Learner Phase}
  - Randomly select another learner  $X_j$ , such that  $j \neq i$
  - If  $X_i$  is better than  $X_j$ , i.e.  $f(X_i) < f(X_j)$   $X_{inew} = X_i + \text{rand}(0,1)(X_i - X_j)$
  - Else  $X_{inew} = X_i + \text{rand}(0,1)(X_j - X_i)$
  - End if
  - If  $X_i$  is better than  $X_i$ , i.e.  $f(X_i) < f(X_j)$   $X_i = X_{inew}$
  - End if {End of learner Phase}
- End

□ For

o Set  $k = k + 1$

o End while



**Fig. 1 Flowchart of TLBO algorithm (2012)**

### 3.2 Jaya Algorithm

This algorithm is mainly depends on the logic of best and worst solutions i.e. accepting best solution and rejecting worst solution as per criteria. The selection of best solution and rejection of worst solution is done with the help of equations and random numbers which are used to generate modified values of solutions. The solutions are generated by Rao et al. (2016) using the following equations:

$$X'_{j,k,i} = X_{j,k,i} + r_{1,j,i} (X_{j,best,i} - |X_{j,k,i}|) - r_{2,j,i} (X_{j,worst,i} - |X_{j,k,i}|) \text{ where, } X_{j,best,i} = \text{Best value of 'j' variable for best solution, } X_{j,worst,i} = \text{Worst value of 'j'}$$

variable for worst solution,  $X'_{j,k,i}$  is the modified values of  $X_{j,k,i}$ ,  $r1_{j,i}$  and  $r2_{j,i}$  are two random numbers used to generate new values of  $X_{j,k,i}$ . " $r1_{j,i} (X_{j,best,i} - |X_{j,k,i}|)$ " is the tendency of solutions getting closer to best solution and " $r2_{j,i} (X_{j,worst,i} - |X_{j,k,i}|)$ " is the tendency of

solutions avoiding worst solution,  $X'_{j,k,i}$  is accepted solution if it gives better value as desired. All accepted values are maintained at the end of iteration and these values become an input for next iteration. The flowchart for Jaya algorithm is given in Fig. 2.

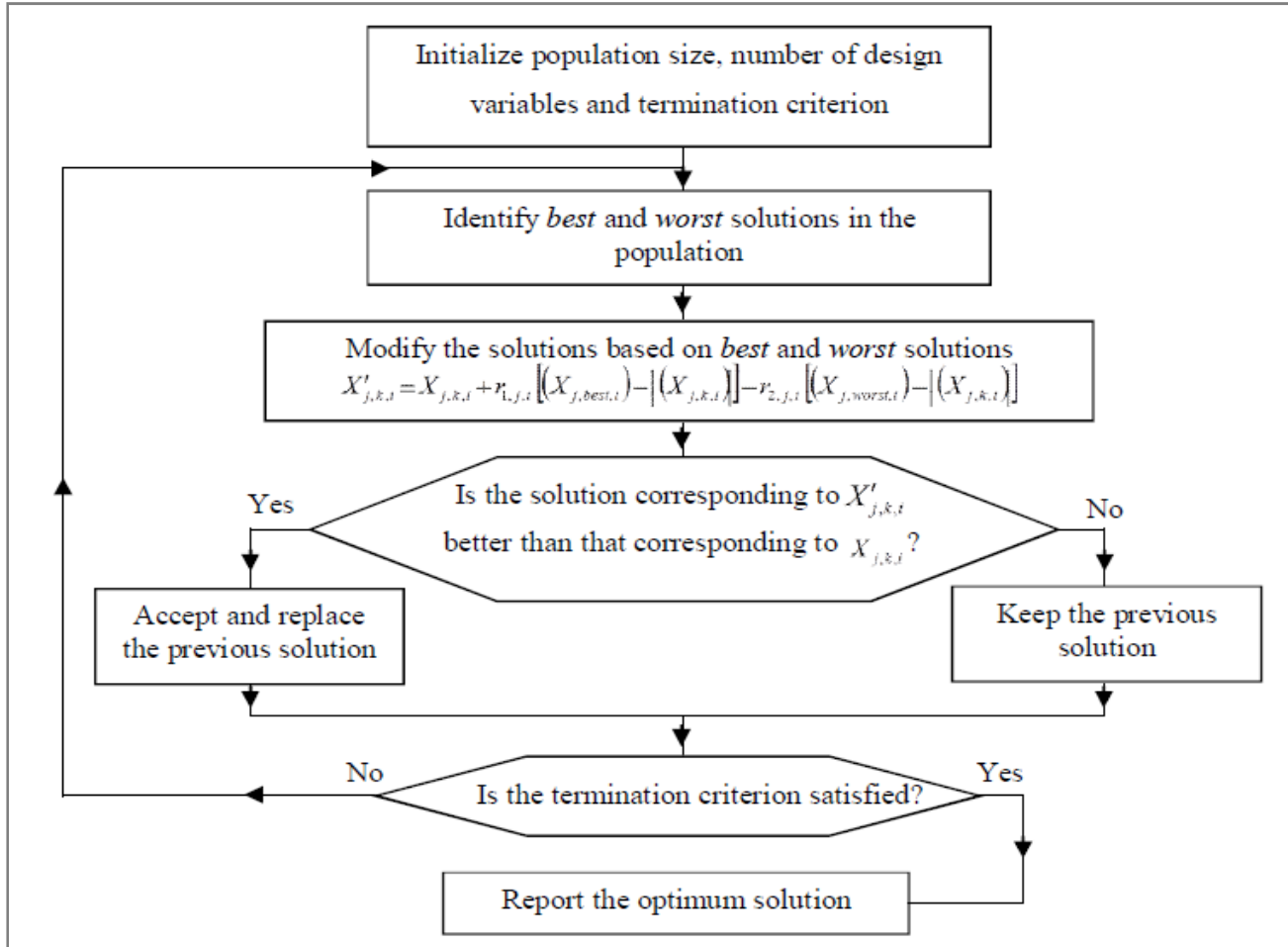


Fig. 2 Flowchart of Jaya Algorithm (2016)

#### 4. EXPERIMENTATION AND MATHEMATICAL MODEL FOR DRILLING OPERATION

Chaudhary et al. (2014) examined the effect of drilling parameter on Aluminum Matrix Composites (AMCs) and Hybrid Aluminum Matrix Composites (HAMCs) materials of 6070 Al alloy by varying input process parameters like speed, feed and point angle of drilling process. The process parameters ranges for speed ( $v$ ), feed( $f$ ) and point angle( $h$ ) are 110 - 280 (rpm), 0.075 - 0.250 (mm/rev) and 110 - 120 (degree) respectively.

The mathematical model for MRR given below:

$$MRR = + 2294.68 + 0.46639 * v - 1859.72123 * f - 40.40270 * h + 1.40228 * v * f + 0.011512 * v * h +$$

$$18.57481 * f * h - 4.0780E-003 * v^2 - 606.3304 * f^2 + 0.16802 * h^2$$

#### 5. RESULTS AND DISCUSSION

The MRR is used as objective function and process parameters limits are applied as constraints and optimum solutions are found out using selected Jaya algorithm and TLBO algorithms. The selected algorithm results are validated by comparing with actual experimental results which depicts that selected algorithm results are very much closer to actual which shows that selected algorithms are practicable and accurate and shows the superiority of the algorithms. The results obtained after running the parameters of drilling process using selected optimization algorithms are given in Table I.

**TABLE I: Results of drilling process parameters**

Technique	Iteration Numbers	Speed (v) rpm	Feed (f) mm/rev	Point angle (h) degree	MRR
TLBO	100	280	0.250	120	<b>216.099</b>
JAYA	100	280	0.250	120	<b>216.099</b>
RSM	---	280	0.250	119.19	209.925

## 6. CONCLUSION

The present work analyzed the various manufacturing processes with their process and response parameters. The multi-objective decision-making methods are versatile in nature. These optimization algorithms are more accurate and effective than other conventional methods of mathematics. The optimization span i.e. running the span of the optimization process is tremendously smaller as compared to other tools of optimization. The MODM methods used viz. Jaya and TLBO are very much adaptable and easy to apply for any optimization problem like constrained and unconstrained, single objective and multiple objectives etc. These methods are derived from the natural phenomena of particle movement, honey bee structure, infinitely temperature decrement and teacher-learner philosophy hence very easy to understand.

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# Mamdani Verses Sugeno Fuzzy Inference Approach for Adaptive Cruise Control

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**Abstract** - An adaptive cruise control (ACC) which is used for control speeds of vehicle on highway road and maintain safe distance between vehicles. This paper compares Mamdani and Sugeno fuzzy inferences to find comfortable ride with safety and precision for ACC. Distance and relative speed between two vehicles are taken as inputs to fuzzy controller to determine desired speed. Mamdani inference gives equivalent weightage to both inputs, whereas Sugeno inference gives flexibility to user in terms of assigning the weightage. To compare evaluation of parameters, model for ACC using Mamdani and Sugeno inference were developed on MATLAB platform. Results show that in Sugeno system we can control output more precisely as one can give any of desired output membership function linearly or constant. Mamdani inference is easier for human to give input whereas Sugeno is complex but give merit over Mamdani inference especially for smoother ride, computationally efficient and less processing time.

**Keywords**- Fuzzy Logic, Adaptive Cruise Control, Mamdani Inference, Sugeno Inference

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## 1. INTRODUCTION

Cruise control is designed to solve a problems such as fatigue duty faced by the drivers and traffic accident (Sandhya and Shreela, 2015). When driver ride vehicle on highway both front driver and self-driver need consciously control the speed of vehicle. When one of them miss concentration accident happen and to avoid that adaptive cruise control (ACC) is used. ACC system reduces the driver's tasks for adjusting the gas pedal, brake and checking dashboard speedometer frequently (Munyaneza, Munyazikwiye and Karimi, 2015). The drawback of cruise control system (CCS) was not able to automatically reduce speed when dangerous situation such as a vehicle in front of him suddenly slows down or stop (Basjaruddin et al., 2014). It can be control with fuzzy logic controller because it has vagueness in inputs for example distance between the vehicle constantly changing and speed of both vehicle also changing which needs to be control according to distance between them and speed variation between them. In addition to maintaining speed, ACC was also designed to prevent rear-end collision because of vehicles following too closely (Basjaruddin et al., 2014). Munyaneza, Munyazikwiye and Karimi (2015) showed that better control performance and great stability can be estimated from fuzzy controller compare to PID controller. Fuzzy logic controller are best for control the speed of vehicle as it provides smoother response because of lower percentage overshoot and peak amplitude.

This paper proposes two most popular techniques of fuzzy inferences system (FIS) i.e. Mamdani interface and Sugeno interface to solve ACC problem. The most primary difference between Mamdani FIS and Sugeno FIS is the

mode, Mamdani-type FIS uses the method of defuzzification of a fuzzy outcome, whereas Sugeno-type FIS uses weighted average to calculate the crisp outcome (Hamam and Geogranas, 2008). Mamdani system require fuzzy set for inputs and outputs but Sugeno system require only fuzzy set for input and for output it is linear or constant.

The rest of this paper is organized as follows. Section 2 briefly reviews the literature control system for ACC. Section 3 presents the proposed FIS using Mamdani and Sugeno approach.

Section 4 gives comparison between these two approaches. Finally, conclusions are presented in Section 5.

## 2. LITERATURE REVIEW

Asere, Lei and Jia (2015) tested PI controller and fuzzy controller for cruise with three mass values (3000kg, 2200kg and 1000kg) in simulink model, which shows that fuzzy controller has very significant response time which is 6 second and PI controller took 21 second. Mathematical model was developed for Fuzzy logic controller and PID controller for vehicle shows that fuzzy logic controller has small overshoot and small amplitude compared to PID controller (Munyaneza, Munyazikwiye and Karimi, 2015). Fuzzy logic is simpler to implement as it eliminates the complicated mathematical modeling process (Nour, Ooi and Chan, 2007). The advantages of using Mamdani Fuzzy inference system come from the easiness of formalization as well as from the interpretable nature of the rule base, whereas the advantages of using Sugeno Fuzzy inference system come from the computational efficiency, accuracy and robustness when in presence of noisy input data such as sensor data (Hamam and Geogranas, 2008).

Devi and Soranamageswari (2016) used hybrid technique of neuro fuzzy system and in fuzzy system they used combination of Mamdani and Sugeno inference type for image processing application. They compared the four different images with same pixel density to see graphically which give better results among the noisy, neuro-fuzzy(sugeno), neuro-fuzzy (hybrid) to find that noise density in hybrid neuro-fuzzy system is low compare to convetional method and neuro-fuzzy (sugeno) type.Mamdani and Sugeno type inference controller have almost same response time and both can provide a good choice for the control of nonlinear ship lift feedback fin stabilizing systems (Chang and Hsu, 2015).Sugeno FIS model not only provides more accurate auto-correlation peak values but it is also computationally more efficient than the Mamdani type FIS for the Mitigation of Environmental Temperature Variations (Reis and Raddo, 2015). According to Singla (2015) comparative study of Mamdani andSugeno for diagnosis of diabetes, shows that sugeno is more accurate as compared to mamdani. Mamdani FLC is better smoothness as compared to Sugeno type FLC, but requires more memory for its implementation for robot path planning (Farooq et al., 2011).

Vukic and Velagic (1999) conducted comparative analysis of Mamdani and Sugeno for autopilots for ships and found performance of Sugeno is slightly better than Mamdani.A Comparison of Mamdani and Sugeno Fuzzy Inference Systems for Chaotic Time Series Prediction, shows that Sugeno FIS demonstrated a more accurate approximation and prediction, a faster processing, more compact (Wang and Chen, 2012). Jassbi et al., (2006) Showed that Sugeno FIS does not only performed better in case of processing time but also performed better in the other tests, showing that the structure of Sugeno FIS is more robust when in presence of noisy input data, also observed that when the fuzzy sets overlap, the Sugeno FIS is more sensitive in too much imprecision in the input representation. Farooq et al., (2011) showed that Mamdani FLC consume more memory for its implementation as compared to Sugeno type FLC, which can be a real time constraint and making the rule base larger, also showed that Mamdani FLC takes 128 Bytes RAM whereas Sugeno FLC takes 29 Bytes RAM. In computational terms, a Sugeno Fuzzy inference system is more efficient than a Mamdani Fuzzy inference system because it does not involve the computationally expensive defuzzification process (Jassbi et al., 2007).

### 3. PROPOSED FIS FOR MAMDANI AND SUGENO APPROCH.

#### 3.1 Control System For ACC

Block diagram for adaptive cruise control as shown in Figure 1.

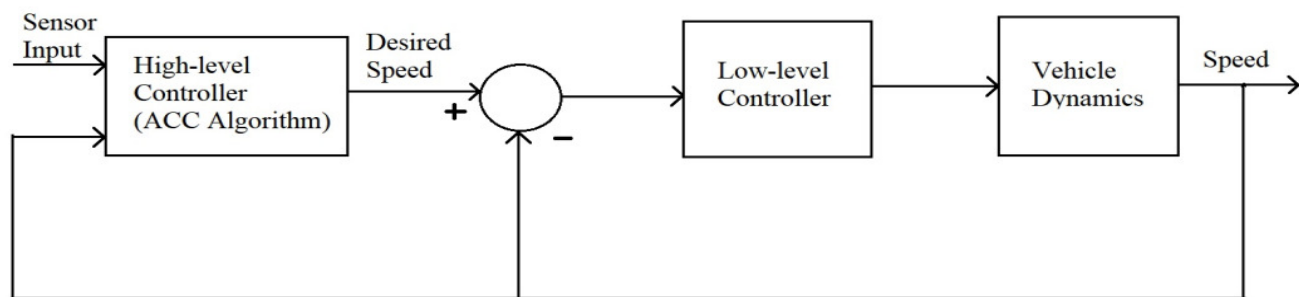


Fig. 1. Block diagram for ACC [Basjaruddin et al., 2014]

There are two level of controller named as High-level controller and Low-level controller. Our main concern is developing High-level controller algorithm based on fuzzy logic Mamdani inference and Sugeno inference. From fuzzy logic controller we get desired speed. Output of high-level controller is set point for low-level controller. In Low-level controller there are speed sensor which measure speed of vehicle. Vehicle dynamics which is actuator used for gas pedal and brake. So in this study our main concern is on high-level controller.For this study we are taking same inputs, same rule base and approximately same output values for Mamdani and Sugeno inference for observing the output.

#### 3.2 ACC Algorithm Based on Mamdani FIS

Block diagram for High-level controller based on Mamdani FIS shown in Figure 2

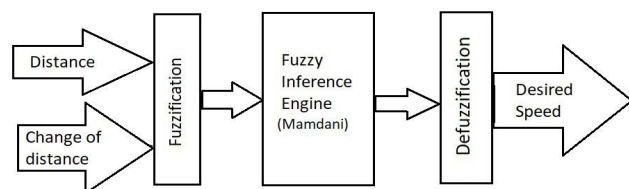


Fig. 2 Block diagram of High-level controller based on Mamdani FIS [Basjaruddin et al., 2014]

It takes two as an input first is *distance* between ego vehicle (EV) which is equipped with ACC and leading vehicle (LV) which is in front of EV and second is *change of distance* between EV and LV. Fuzzy inference engine used in the system is Mamdani. Defuzzification is done by centroid method. Output of high-level controller is desired speed.

As shown in Figs. 3 to 5 for *distance* membership function is divided into three parameters namely near, medium and far and for *change of distance* membership function is also divided into three parameters namely small, medium and big. Output membership function is also divided as slow, medium and fast. Table I shows the rule base for mamdani.

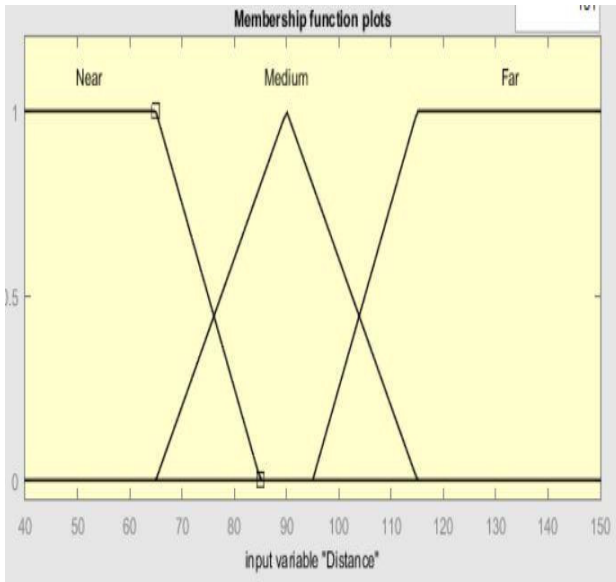


Fig. 3 Membership function of distance

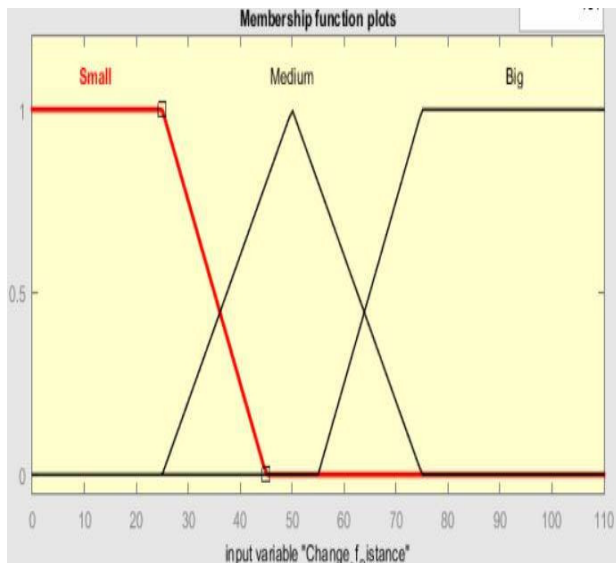


Fig. 4. Membership function of change of distance

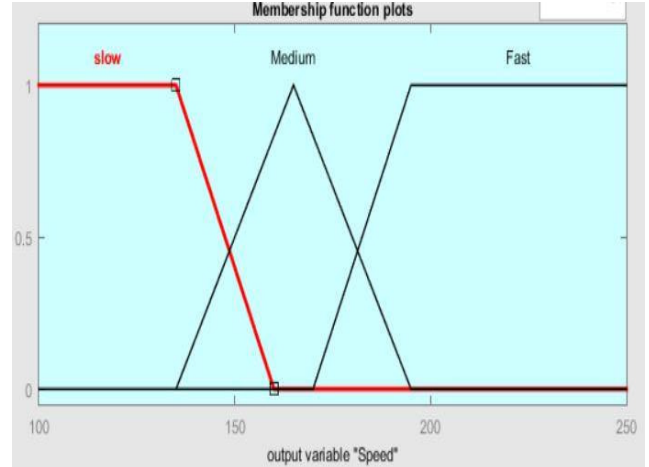


Fig. 5. Membership function of desired speed

TABLE I: Rule base for Mamdani

Change of distance				
		small	medium	big
Distance	near	slow	slow	slow
	medium	medium	medium	slow
	far	fast	fast	medium

### 3.3 ACC Algorithm Based on Sugeno FIS

Block diagram for High-level controller based on Sugeno FIS shown in Figure 6. It is same as Mamdani FIS only difference at defuzzification part. It can be seen in block diagram figure 6. For this study we have set Sugeno FIS inputs membership function same as in Mamdani FIS Figs. 3-4. Rule base is also same as Mamdani FIS as shown in Table I. For output considering two types one is constant and second is linear that is weighted average to compute crisp output.

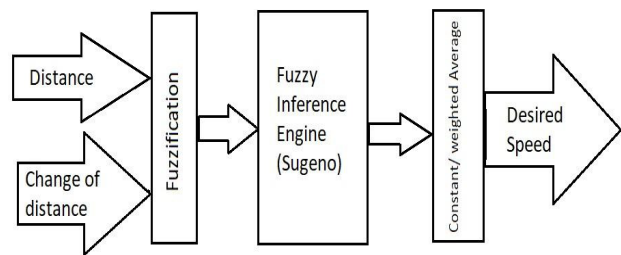


Fig. 6 Block diagram of High-level controller based on Sugeno FIS.

#### 3.3.1 Sugeno FIS With Constant type

Output from Sugeno FIS is described by three singletons. In constant type a constant value is set for output. For this study we have chosen approximately same output value which is taken in Mamdani FIS. Fig. 7 shows that output membership function for slow desired speed is 135.

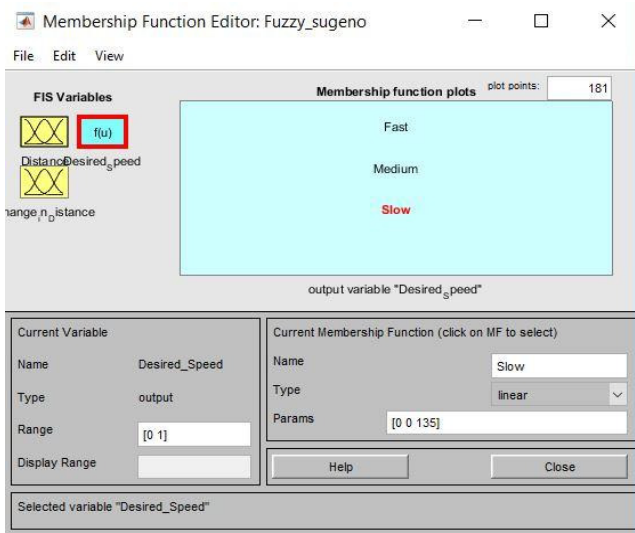


Fig. 7 Output MF for Sugeno (constant type).

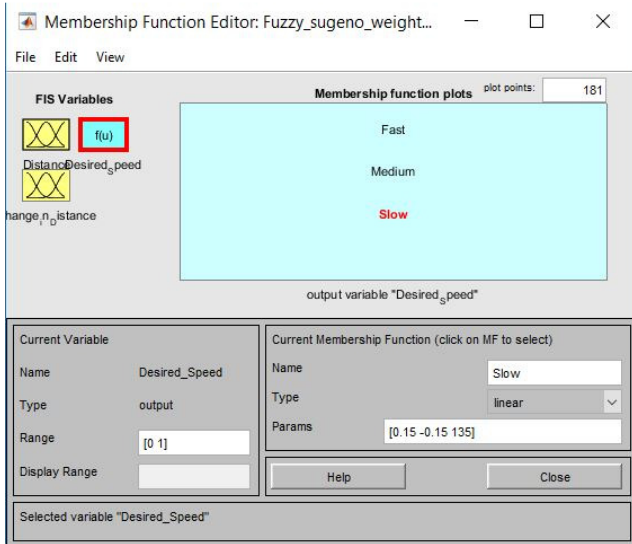


Fig. 8. Output MF for Sugeno (linear type).

Similarly, we took 165 for medium and 195 for fast. A typical rule in a Sugeno fuzzy model has the form (Mathworks):

If Input 1 is  $x$  and Input 2 is  $y$ , then Output is  $z = ax + by + c$  (i)

For constant type  $a=b=0$ ,  $z = c$  and it is also known as zero order sugeno model.

### 3.3.2 Sugeno FIS With Linear Type

In Eq. (i) if  $a$  and  $b$  values are not equal to zero then It is a linear type or weighted average type. Fig.8 shows output membership function for sugeno (linear type).

For Slow,  $a = 0.15$  and  $b = -0.15$

$$u1 = 0.15*a - 0.15*b + 135 \quad (ii)$$

For Medium,  $a = 0.1$  and  $b = -0.2$

$$u2 = 0.1*a - 0.2*b + 165 \quad (iii)$$

For Fast,  $a = 0.1$  and  $b = 0.1$

$$u3 = 0.1*a + 0.1*b + 195 \quad (iv)$$

In equation (ii), (iii) and (iv) weightage is given. According to given weightage it is more sensitive to *change of distance* than *distance*.

## 4. COMPARISON BETWEENMAMDANI, SUGENO (CONSTANT TYPE) AND SUGENO (LINEAR TYPE)

Fig. 9-10 shows the surface view in 2 axis, distance vs desired speed and change of distance vs desired speed. Although inputs membership function and rule base is same for both mamdani and sugeno FIS. And output membership function for both approximately same but surface view is different one from another. Range of speed for all three is little different.

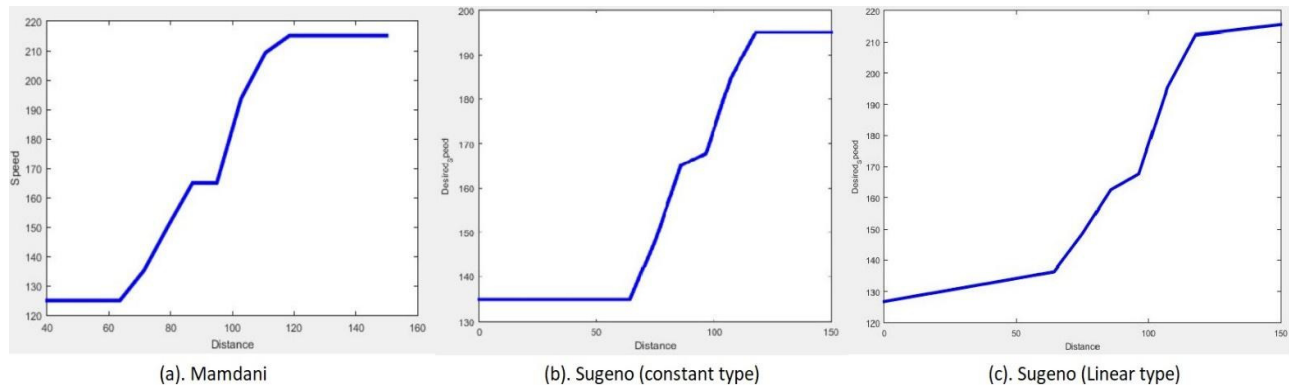


Fig. 9. Distance vs desired speed



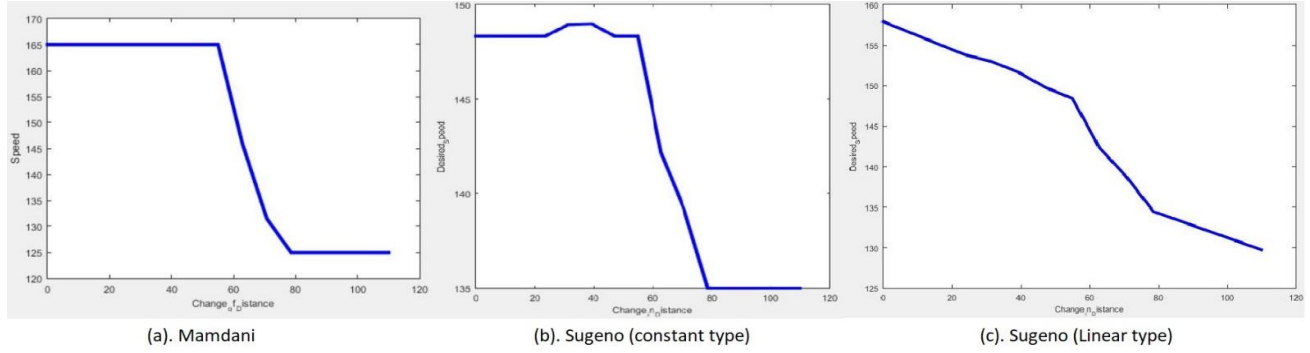


Fig. 10. Change of distance vs desired speed

TABLE II: Comparison table for mamdani, sugeno (constant type) and sugeno (linear type)

Factors	Mamdani	Sugeno (constant type)	Sugeno (linear type)
Range of speed for <i>distance</i>	125-215= 90	135-195= 60	128-215= 87
Range of speed for <i>change of distance</i>	125-165= 40	135-148=13	130-158= 28
Range of working <i>distance</i>	63-118 = 55	60-115 =55	0-150= 150
Range of working <i>change of distance</i>	57-79 = 22	1) 23-49 =26 2) 58-80= 22	0-110 = 110

Table II shows the comparison between Mamdani, Sugeno (constant type) and Sugeno (linear type). Range of speed for *distance* is vehicle speed range for *distance*, within it will accelerate or deaccelerate and beyond this range it will have constant speed. As we can see the Range of speed for *distance* is almost same for mamdani and sugeno (linear type) FIS but there is difference in sugeno (constant type) FIS which is due to our set constant value. Which can be modified to obtain desired result. Similarly, Range of speed for *change of distance* is different for all of three. In Fig. 10 (c) shows that it doesn't have any constant speed which is present in mamdani and sugeno (constant type) FIS. Range of working *distance* is a distance range in which vehicle will accelerate or deaccelerate and beyond this range it will have constant speed. Range of working distance is same for mamdani and sugeno (constant type) FIS but in sugeno (linear type) FIS there is big difference it is due to

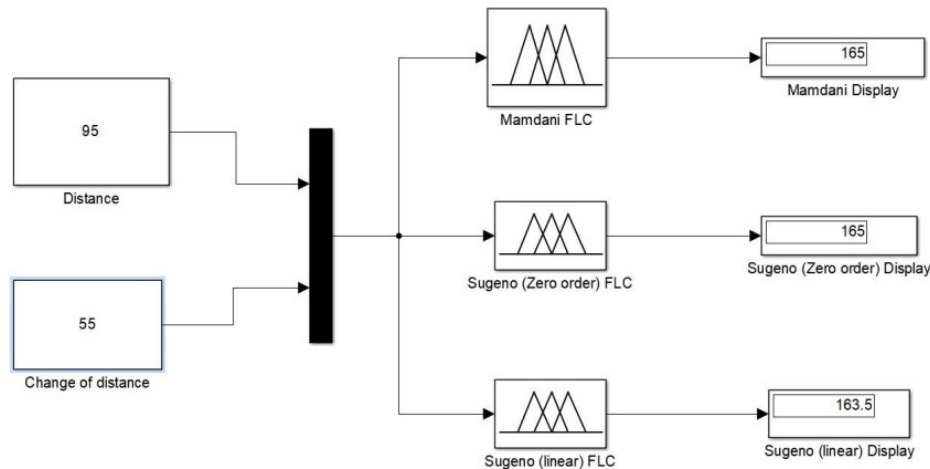
weightage we have assign to it. Its working distance range is 0-150 which means it will have response for any of distance input. It will not give any constant speed. Similarly, Range of working change of distance is same for both mamdani and sugeno (constant type) FIS but in sugeno (constant type) FIS have protrude at 23-49 distance range. Which can be avoided by giving proper inputs membership function and output. Range of working change of distance for sugeno (linear type) FIS is 0-110. It means it is utilizing whole change of distance range. There is no constant speed. We can introduced both constant type and linear type in one sugeno FIS model to obtain result as per our requirement.

Fig. 11 shows rule viewer for low desired speed and Fig.12 shows Simulink model for medium desired speed similarly we can get result for any desired value. Fig. 13 shows surface view for input and output relationship.

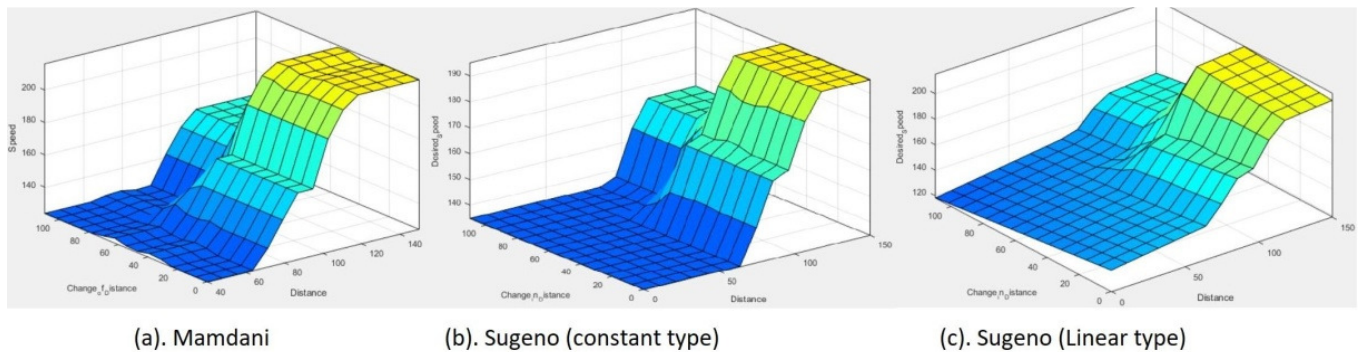


Fig. 11. Rule viewer for low desired speed





**Fig. 12. Simulink model for medium desired speed**



**Fig. 13. Surface view for Mamdani and Sugeno (constant and linear) FIS**

## 5. CONCLUSION

Mamdani and Sugeno FIS is implemented in matlab platform. It has seen that we can get same results as Mamdani FLC gives, can be created by Sugeno FLC. As sugeno has lots of advantage such as less processing time, less RAM consumption, computationally effecitent and we can assign weightage to input. Mamdani FIS is good to give output membership function whereas Sugeno FIS require trial error and effort to give proper weightage or constant value for output. Sugeno FLC will save lots of memory and processing time in ACC which will be helpful when vehicle riding on highway road with full speed and its little bit fast reponse can make a significant difference in controlling. Due to this it is more safer than Mamdani FIS. As a future research one can introduce more input such as camera input with existing distance and change of distance input so that it will give more control on desired speed.

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# A Mathematical Model to Solve the Problem of Dynamic Cell Formation and Plant Layout Considering Machine Reliability

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**Abstract:** Cellular Manufacturing is a major component of lean manufacturing which can be achieved by cell formation of machine types. Several methods have been developed for obtaining efficient cell formation in Cellular Manufacturing Systems. However as this has been done for ideal conditions and environments such as infinite machine capacity and 100% machine runtime, it doesn't give a near accurate solution. This paper takes into account machine reliability and breakdown conditions to provide a comparatively more accurate solution and suggests a mathematical model to place the cells formed in the available locations of a plant. GA Toolbox on MATLAB R2016a has been recommended as the tool for solving the model for an accurate result.

**Keywords:** Cellular Manufacturing, Cell Formation, Plant Layout, Mathematical Model, Machine Reliability

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## 1. INTRODUCTION

Cellular Manufacturing (CM) is a technique in Group Technology which has been known to improve the efficiency and flexibility of a modern plant. It makes a plant more suitable for environments such as Just In Time Manufacturing, and Flexible Manufacturing Systems. CM is usually associated with reduction in set up time, work in process inventory reduction and improvement of machine utilization and quality of product. The design of a CM System consists of the following aspects.

- a) Cell Formation (CF): Grouping of parts with similar processing requirements into part families and assign them to corresponding machine families.
- b) Group Formation (GF): Laying out machines within a cell
- c) Plant Layout (PL): Laying out cells with respect to each other on the available locations in the Plant.

We have developed a mathematical model which considers the Dynamic cell formation problem along with machine reliability factors and then placed the cells obtained in the available locations of a plant. The model has been solved using Genetic Algorithm toolbox on MATLAB 9.0, as it gives efficient results in minimum processing time and requires minimum knowledge of coding. The rest of the paper has been organized as follows. Literature review related to CF and PL has been provided in Section 2. Section 3 consists of the mathematical model that has been proposed, and its modeling on MATLAB. The conclusion and future scope has been presented in Section 4.

## 2. LITERATURE REVIEW

In this section, we present the related literature survey of studies regarding the sub categories in CMS, namely Cell formation, Machine grouping and Plant layout. Since numerous researchers have worked in the field, we have selected the papers in a way to maximize the types of techniques used. The research work on each of the sub categories has been separately presented in three subsections below.

### 2.1 Cell formation problem

The cell formation problem is the sub category with maximum amount of research work available. Papers from year 1976 have been chosen to study the development in the procedure of cell formation. It also gives a better stand position to identify the existing gap.

One of the earliest methods in CF is the Direct Clustering Algorithm (Mulvey and Crowder, 1979; Chan and Milner, 1982; Gupta, 1991; Ng, 1993; Nair and Narendran; 1998). DCA aims at clustering the machine-part factor (marked as '1' if a part is machined on a machine, else '0') towards the diagonal of a matrix which has Parts in the row and machines in the column, vice versa. The aim of DCA is to reduce exceptional elements (1s which do not have neighbors in the matrix) and voids (0s present in a cluster of 1s.) Since the introduction of the DCA technique, several heuristics and non-heuristics methods have been developed and experimented upon. A summary of these have been provided below.

**TABLE 1**

<b>Sr. No.</b>	<b>Method</b>	<b>Author/s</b>	<b>Year of Publication</b>	<b>Remarks/ Striking feature of Paper</b>
1)	Mathematical Model	Defersha and Chen	2006	Provided a list of attributes which can be taken into account while problem formulation
		Shiyas and Pillai	2014	Capable of providing multiple potential solutions
2)	Similarity Co-efficient	Gupta	1993	Considers alternative routing
		Garbie, Parsaei and Leep	2008	
3)	Neural Networks	Venugopal and Narendran	1994	
		Chen and Cheng	1995	
		Safaei, Saidi-Mehrabad and Tarakkoli-Moghaddam	2008	Used fuzzy logic; considered dynamic and uncertain conditions
		Manimaran et al	2014	Used Adaptive Resonance Theory (ART1) networks
4)	Heuristics	Harhalakis, Nagi and Proth	1990	
		Lin et al	1996	Cell imbalance costs are considered
		Mukattash, Adil and Tahboub	2002	Alternative process routing with higher flexibility
		Ouk Kim, Baek and Baek	2004	Alternative part routes and consideration of machine sequences
5)	Simulated Annealing	Sofianopoulou	1999	Alternative process plan and machine replication
		Keeling, Brown and James	2007	Measures grouping efficiency
		Wu, Chang and Chung	2008	
		Mohammadi and Forghani	2015	Duplicate machine consideration
		Hodiya	2015	Considers CF and PL simultaneously
6)	Genetic Algorithm	De Lit, Falkenauer and Delchambre	2000	Grouping genetic algorithm with large capacities
		Mak, Wong and Wang	2000	Maximises bond energy of incidence matrix
		Onwubolu and Mutingi	2001	
		Zolfaghari and Liang	2004	
		Goncalves Filho and Tiberti	2006	Group Genetic Algorithm
		Wu et al	2007	Considers CF and PL simultaneously
		Mahdavi et al	2009	Alternative cell routings

Sr. No.	Method	Author/s	Year of Publication	Remarks/ Striking feature of Paper
7)	Others	Deljoo et al	2010	Dynamic cell formation
		Shahparvari and Chiniforooshan	2012	Alternative process routing
		Boe and Cheng	1991	Close neighbor algorithm
		Chung, Wu and Chang	2011	Tabu search algorithm
		Logendran and Karim	2003	
		McKendall and Shang	2006	Hybrid ant system
		Fahmy	2015	Linear programming

Genetic Algorithm (GA) works on Darwin's theory of Survival of the fittest. A set of populations are achieved from a given set of parent populations and the off springs giving the best desired results are selected as the next parent population. This process continues till the parent and offspring population are identical. GA has been selected as the tool for solving the CFP as it can work with even a small parent population to give the best results.

## 2.2. Machine Grouping and Plant Layout.

The number of literature available in the area of machine grouping and plant layout is much less compared to research in cell formation. The basic objective in all plant layout problems is to minimize the material handling cost, both intra-cellular and inter-cellular. Balakrishnan et al, 2003 and Kulkarni and Shanker, 2007 used hybrid genetic algorithm; Diaby and Nsakanda, 2006 used large scale capacitated heuristics; Drira, Pierreval and Hajri-Gabouj, 2007 made use of fuzzy formulation; and Kia et al, 2007 as well as Allahyari and Azab, 2017 used simulated annealing to achieve this objective. The most elaborate study was done by Anderson et al, 2006. Each of these papers used a few varying factors in addition to the main cost of intra and inter-cellular material handling cost.

## 3. METHODOLOGY

On studying the literature present in the given field, we realized a lack of a paper in which CMS has been dealt with as a whole, considering all of CF, GF and PL problems together. Thus we developed a sequential model which

when solved would provide machine cell formation as well as locate them on the plant, for a given industry. This section has been divided into 3 subsections, each dealing with an aspect of our model towards CMS.

### 3.1 Cell formation

After going through the various factors that can be considered for a Cell Formation Problem (CFP) as mentioned by Defersha and Chen, 2006, we selected the attributes that are commonly relevant to most industries, and considered the minimum number of attributes required to produce a solution closest to 100 % accuracy.

Before proceeding with the development of the function, 2 papers: Selim, Askin and Vakharia, 1998; Papaioannou and Wilson, 2010 were exclusively referred. These papers provided a summary of existing research up to 1997 and from 1997 to 2008. These papers also provided directions for future research.

We considered a cell formation problem for a dynamic condition taking into account machine reliability. The main objective is to minimize the sum of Operating cost, Inter-cell material handling cost, Machine relocation cost and Breakdown cost. The machine investment cost is also considered, however since it a constant value for a given machine, minimization cannot be achieved. The notations and functions thus obtained are listed below:

TABLE 2

Term	Input Parameter	Term	Input Parameter	Term	Input Parameter
P	No. of part types	$IN_{m,c}$	No. of machines of type m in cell c initially	$MC_m$	Capacity of machine type m
T	No. of periods	B	Batch size for inter-cell material handling	LL	Lower limit of cell size
M	No. of machine types	$\alpha_m$	Purchase cost for machine type m	UL	Upper limit of cell size

Term	Input Parameter	Term	Input Parameter	Term	Input Parameter
C	No. of cells	B _m	Operating cost for machine type m	a _{jpm}	1 if operation j of part p can be done on machine m, else 0
O(p)	No. of operations to be done on part p	g	Intercell material handling cost per batch	MFT _m	Mean time between failures for machine type m
t _{jpm}	Time to perform operation j of part p on machine type m	INS _m	Installation cost for machine m	BD _m	Breakdown cost for machine type m
A	Arbitrary large constant	UNS _m	Uninstallation cost for machine m	V _p	Production volume for part p
D _{pT}	Demand of part p in period T				

### Decision Variables:

1. Nm,c,T - No. of machines of type m in cell c in period T
2. K+m,c,T - No. of machines of type m added to cell c in period T
3. K- m,c,T - No. of machines of type m removed from cell c in period T
4. X_{jpmcT} - 1 if operation j of part p done on machine m in cell c in period T, else 0
5. Z_{jpcT} - 1 if operation j of part p is done in cell c in period T, else 0

$$\begin{aligned} \min(TC) = & \sum_{m=1}^M \alpha_m \times \max\{0, \max\{\sum_{c=1}^C Nm cT - INm c\}\} + \sum_{T=1}^T \sum_{c=1}^C \sum_{m=1}^M \sum_{p=1}^P \sum_{j=1}^{O(p)} D_{pT} \times t_{jpm} \times X_{jpmcT} \times \\ & B_m + \frac{1}{2} \sum_{p=1}^P \sum_{T=1}^T \left[ \frac{D_{pT}}{B} \right] \times \sum_{j=1}^J \sum_{m=1}^M \gamma |Z_{(j+1)pcT} - Z_{jpcT}| + \\ & \sum_{T=1}^T \sum_{m=1}^M \sum_{c=1}^C K_{mcT}^+ \times INS_m \\ & + \sum_{T=1}^T \sum_{m=1}^M \sum_{c=1}^C K_{mcT}^- \times UNS_m + \sum_{T=1}^T \sum_{p=1}^P \sum_{j=1}^{O(p)} X_{jpmcT} \times \\ & \frac{V_p}{MFT_m} \times t_{jpm} \times BD_m \end{aligned}$$

Such that:

$$\sum_{c=1}^C a_{jpm} X_{jpmcT} = 1 \quad (i)$$

$$X_{jpmcT} \leq a_{jpm} \quad (ii)$$

$$\sum_p \sum_{j=1}^{O(p)} D_{pT} \times t_{jpm} \times X_{jpmcT} \leq MC_m \times N_{mcT} \quad (iii)$$

$$LL \leq \sum_{m=1}^M N_{mcT} \leq UL \quad (iv)$$

$$N_{mc(T-1)} + K_{mcT}^+ - K_{mcT}^- = N_{mcT} \quad (v)$$

$$IN_{mc} + K_{mc1}^+ - K_{mc1}^- = N_{mc1} \quad (vi)$$

### 3.2 Machine Grouping and Plant Layout

Machine grouping and plant layout have been considered together. The common objective for both the problems is to reduce the total material handling cost. Thus, machines within a group and the groups within the plant are organized in such a way that the total cost (TC) is reduced. We have considered a linear layout with M linear locations.

We have the following definitions:

1. D=[d_{ij}] is the distance matrix between which gives movement cost 2 locations
2. F = [f_{pq}] is the flow matrix to determine the movement between 2 cells p and q

We obtain the function as:

$$\text{Min TC} = \sum_{p>q}^M \sum_{i>j}^M d_{ij} \times f_{pq} \times X_{pi} \times X_{qj};$$

Such that:

$$1. \sum_{i=1}^M X_{pi} = 1 \quad p=1 \dots M$$

$$2. \sum_{p=1}^M X_{pi} = 1 \quad i=1 \dots M$$

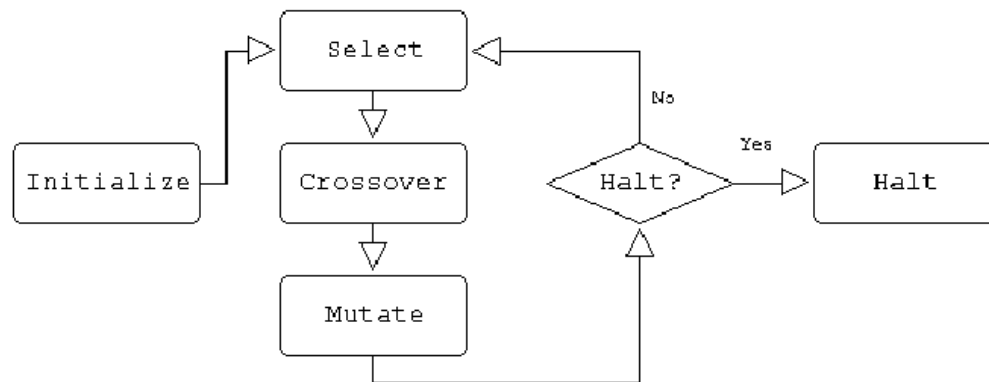
$$3. X_{pi} = (0,1) \quad p,i= 1 \dots M$$

### 3.3 Genetic Algorithm Implementation

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

MATLAB combines a desktop environment tuned for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly.

Out of Various Toolbox available we make use of GA of the Optimization tool to carry out multiple iterations. It makes use of the Genetic algorithm process, which has been graphically explained below:



**Fig.1. Genetic Algritm Flowchart given by Mouradian, Hamann and Rosenbaum, 2012.**

#### 4. CONCLUSION AND FUTURE SCOPE

Our Paper is based on several assumptions and still hasn't considered a few variable objectives. Also, several data need to be input by the user; subject to their available resources. Another short coming is that a user interference is required to transfer output from CF model to plant-layout model. All these can be worked on in Future Research.

Proposed Model and group efficiency calculation still remains to be implemented and verified.

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SECTION – IX

ROBOTICS AND ARTIFICIAL INTELLIGENCE

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# Selection and Performance Analysis of a Robot Using AHP

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**Abstract:** The aim of this paper is to find the best manipulator that can be used in industries using the multiple attribute decision making method and also do the performance analysis of that selected manipulator to give the efficiency of that manipulator for industrial application. Different types of robots having different kinematic links and of different types are been considered and best one out of these based on attributes like Purchasing cost, Loading Capacity, Repeatability Error, Man Machine Interface and Programming Flexibility is selected. In this paper Analytical Hierarchy Process (AHP), a multiple attribute decision making method (MODM) is used to select the best manipulator among the alternatives by giving weightage to each attribute. The selected manipulator is designed and its performance analysis is carried out by developing the mathematical equations based on its kinematic chains and finding the Jacobian matrix. Jacobian matrix along with mathematical representations of kinematic links of manipulators are used to find performance factors like condition number, minimum singular and stiffness index. Matlab is used for finding best manipulator using AHP and also for doing performance analysis.

**Keywords:** MODM, AHP, Performance Analysis

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## 1. INTRODUCTION

Now a days the use of robots has spread to all the fields. Especially in industries robots has got a great work to do. There are many works in industries which are risky to human and some works are repetitive which a human will not have an interest to do those works. In this types of robots are serving human a lot. There are different types of robots that are used in industries out of which Series manipulators and Parallel manipulators are considered as mostly used industrial robots. In this paper few of the mostly used Series and Parallel manipulators are considered and a best one is selected. This paper helps to suggest the type of manipulators that is most suitable to use in industries. In industries robots are used for many works like pick and place, welding, different operations on lathe, miller, planar and also in automatic retrieval system. The use of robots in industries helps to improve the quality and quantity of manufacturing.

There are many methods of multiple attribute decision making but for this problem Analytical Hierarchy Method is most suitable as there are many attributes and each attribute is given a particular weightage. Based on the mathematical equations the code is written in Matlab.

The designing of the best manipulator selected from AHP gives a broad knowledge about its kinematic links and helps in forming the mathematical equations that are used in inverse kinematics. Mathematical representations of different links of the selected manipulator are used for

coding and finding the Jacobian along with analysis of its performance.

## 2. PROBLEM STATEMENT

To select a best manipulator from the available manipulators for industrial applications using Analytical Hierarchy Process and do the performance analysis of that selected manipulator using mathematical representation of the links and inverse kinematics.

## 3. ANALYTICAL HIERARCHY PROCESS (AHP)

There are many analytical techniques out of which AHP is one among the methods which can be used in very complex situations. AHP was developed by Saaty in which a decision making problem is decomposed into a system of hierarchies of attributes, alternatives and objectives (1). AHP hierarchy has to be done at many levels to describe about the specific decision to a full extent. AHP is a useful method and methodology as it has many number of characteristics with specific functions. This method has the ability to handle different situations where decision has to be taken which involves the decisions having the subjective kind of judgments, consider many persons who can take the decisions and also has the capability to provide the preference in a consistent way (1). Its methodology is like it is been designed in such a way like how the people think. AHP can powerfully deal with objective function and subjective function attributes. The purpose of AHP is to structure complexity in gradual steps from the large to the small, or the general to the particular, so that we can relate them with greater accuracy according to our understanding.

Because experience is too vast to lay it out in a single network structure, we are satisfied with piecemeal decompositions and with occasional linkages of them. The purpose is to improve our awareness by richer synthesis of our knowledge and intuition. The AHP is a learning tool. It is not a means to discover the TRUTH because truth is relative and changing. In the AHP, next to setting up a STRUCTURE to represent a problem, the reciprocal property is the most fundamental aspect for creating a SCALE.

#### 4. SELECTION OF BEST MANIPULATOR USING AHP

Different types of Manipulators with their configurations have been taken and using AHP method the best alternative is picked and kinetostatic performance analysis is done. The table showing different robots and their configurations is given below.

**TABLE I: Different Manipulators and their Configurations**

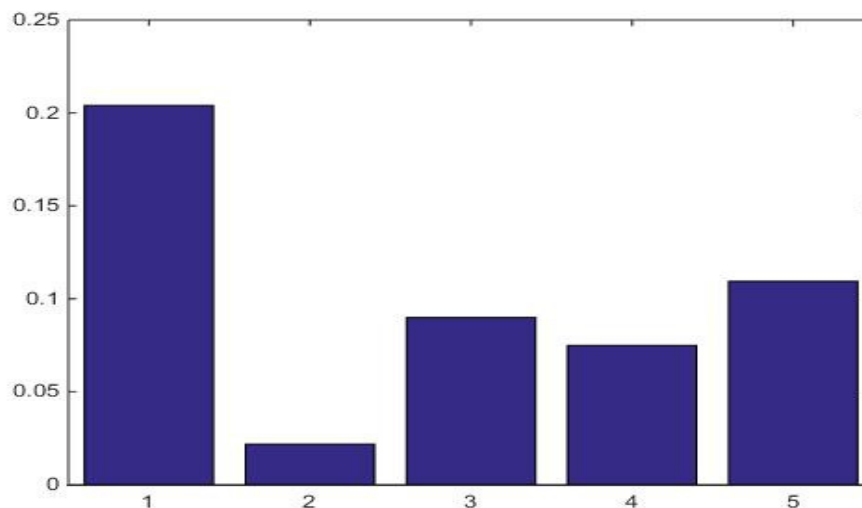
ALTERNATIVES	MANIPULATOR 1	MANIPULATOR 2	MANIPULATOR 3	MANIPULATOR 4	MANIPULATOR 5
Purchasing cost (in dollars)	75	70	73	80	58
Loading Capacity (g)	60	63.5	68	100	25
Repeatability Error (mm)	0.4	0.15	0.1	0.3	0.2
Man Machine Interface	0.2	0.15	0.2	0.2	0.35
Programming Flexibility	0.2	0.15	0.1	0.15	0.1

The different attributes considered in this thesis are:  
 PC — Purchasing cost, LC — Loading Capacity,  
 RE — Repeatability Error, MI — Man Machine Interface  
 PF — Programming Flexibility.

The different alternatives available are:  
 MANIPULATOR 1 — 2 URP-1RPR parallel manipulator,

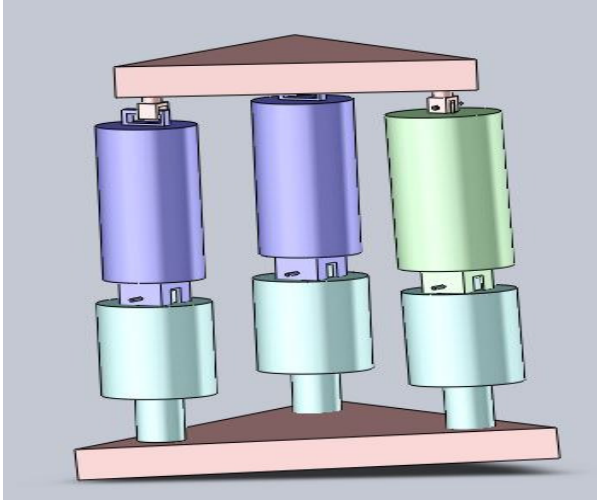
MANIPULATOR 2 — 3RPR parallel manipulator,  
 MANIPULATOR 3 — 3RPR Series manipulator,  
 MANIPULATOR 4 — 3RRR Series manipulator and  
 MANIPULATOR 5 — 4RPR Series manipulator.

According to Analytical Hierarchy process the best alternative is Manipulator 1 which is a 2URP-1RRP parallel manipulator. The bar plot of the best alternatives is given below.



**Fig. 1 Best Manipulator according to AHP**

## 5. PEROFORMANCE ANALYSIS OF 2URP-1RRP PARALLEL MANIPULATOR



**Fig. 2 Kinematic model of 2URP-1RRP Parallel Manipulator**

A 2-URP and 1-RRP kinematic model of the manipulator having three legs is been taken. In this model the two legs have the joints connected with first universal joint then a revolute pair and at the end there is a prismatic pair. The other leg in this kinematic model has two revolute pairs and at the end there is a prismatic joint. Vertices of the output platform are denoted as platform joints  $M_i$  ( $i = 1, 2, 3$ ), and vertices of the fixed base platform are denoted as  $F_i$  ( $i = 1, 2, 3$ ).  $R:O-xyz$ , which is a fixed reference system termed as global reference system is located at the centre of the side  $F_1 F_2$  with the  $z$  axis normal to the base platform and along the  $F_1 F_2 y$  axis is directed. There is another reference frame in the top designated as  $R':O'-x'y'z'$ , is located at the centre of the side  $M_1, M_2$ . The  $z'$  axis is perpendicular to the output platform and along the  $M_1, M_2 y'$  axis is directed. The length of link for each leg is denoted as  $L$ , where  $M_i F_i = L$ ,  $i = 1, 2, 3$ . We should note that the lengths of the three legs might not be same in all the cases. There might be some cases where the lengths of links differ from each other as there is a prismatic link. To start the analysis the known pose of the movable platform has to be taken into account and the positioning vector introduced will determine the position vector  $(O')R$ . Orientation is completely dependent on the  $S$ , it is given by the matrix  $S$ . Then the position vector can be given as

$$(O')_R = (xyz)^T \quad (1)$$

Where there is no movement in  $x$ -direction, i.e.  $x = 0$  and

$$S = \begin{bmatrix} \cos \phi & 0 & \sin \phi \\ 0 & 1 & 0 \\ -\sin \phi & 0 & \cos \phi \end{bmatrix} \quad (2)$$

$$z_1 = \pm \sqrt{L^2 - (-r + y + R)^2} + z \quad (3)$$

$$z_2 = \pm \sqrt{L^2 - (r + y - R)^2} + z \quad (4)$$

$$z_3 = \pm \sqrt{L^2 - (-r \cos \phi + R)^2 - y^2} + r \sin \phi + z \quad (5)$$

By observing the above three equations (3)-(5) one can conclude that the equations end up giving backward kinematics solutions at a given pose of the parallel manipulator. By using "+" instead of signs " $\pm$ " in (3)-(5) one can obtain the inverse configuration.

The formulation of Jacobian matrix and jacobian analysis is simple in terms of series manipulators as they are open chain but in case of parallel manipulators it is a complex situation problem as there are more number of links constituting to form many number of closed loops.

For example let vector  $g$  denote the joint variables which are actuated and for describing the movable pods location vector  $x$  is used. The constraints which are kinematically important and are laid by the legs of the manipulator can be designated usually in the below form.

$$F(x, g) = 0, \quad (6)$$

$$J_x \dot{x} = J_g \dot{g} \quad (7)$$

Where

$$J_x = \frac{\partial F}{\partial x} \quad \text{and} \quad J_g = -\frac{\partial F}{\partial g}$$

The derivation above leads to two separate Jacobian matrices. Hence the overall Jacobian matrix,  $J$ , can be written as

$$\dot{g} = J \dot{x} \quad (8)$$

Where  $J = J_g^{-1} J_x$ . Jacobian matrix is designated in the above equation is noted. The above equation of a parallel manipulator resembles the reverse Jacobian of a serial manipulator.

Jacobian matrix of 2URP and 1 RRP manipulator is obtained by differentiating Eq. (9).

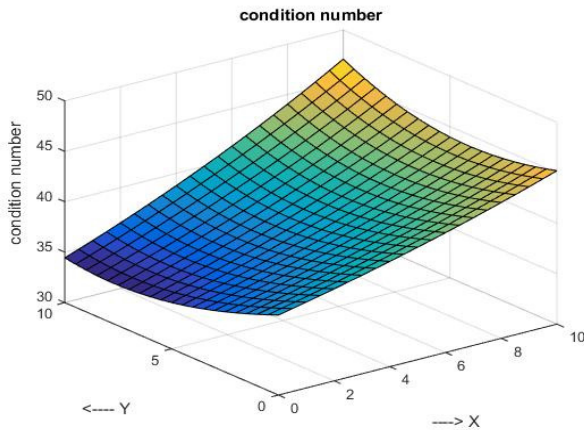
$$J = j_g^{-1} j_x = D^{-1} C \quad (9)$$

$$C = \begin{bmatrix} z - z_1 & 0 & 0 \\ 0 & z - z_2 & 0 \\ 0 & 0 & r \sin \phi + z - z_3 \end{bmatrix} \quad (10)$$

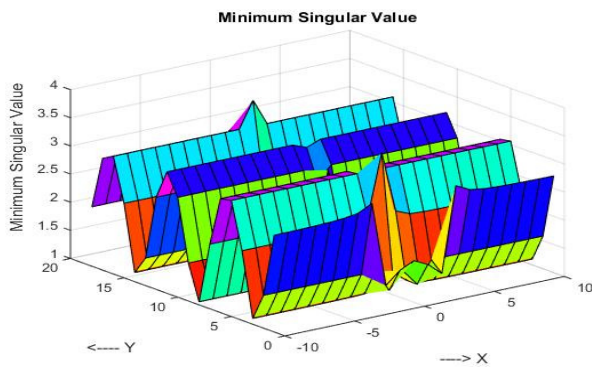
$$D = \begin{bmatrix} -r + y + R & z - z_1 & 0 \\ r + y - R & z - z_2 & 0 \\ y & r \sin \phi + z - z_3 & R r \sin \phi + r(z - z_3) \cos \phi \end{bmatrix} \quad (11)$$

The performance indices namely condition number, minimum singular and stiffness index values are evaluated for the manipulator. All the above mentioned indices are the

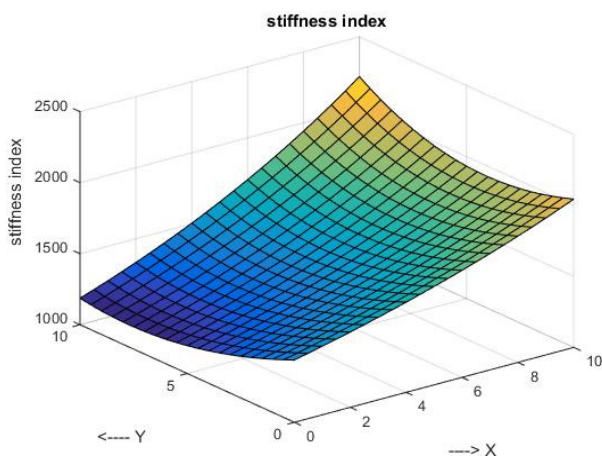
functions of the Jacobian matrix. A Matlab programme is used for the performance evaluation of the manipulator. The outputs from the matlab program are given as input for surface plotting.



**Fig. 3 Variation of Condition Number for a vertical reach ( $z=5$ ) and orientation  $15^\circ$**



**Fig. 4 Variation of Singularity for a vertical reach ( $z=5$ ) and orientation  $15^\circ$**



**Fig. 5 Variation of Stiffness Index for a vertical reach ( $z=5$ ) and orientation  $15^\circ$**

## 6. CONCLUSION

From the above results it is evident that the manipulator selected as best from AHP method is most suitable in industries for doing works like carrying loads as the stiffness index is high at the considered point. The robot also has a low singularity which means that the errors done by the manipulator are less and the good condition number value states that manipulator can get into its path quickly even after committing errors. All the good performances of the manipulator says that manipulator can easily appointed in industries and can be used for vast applications.

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# Automatic Fire Fighting Robotic System

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**Abstract:** The Automation has increased over the past few decades. Robotic systems capable of performing complicated tasks are used in industries and various business organizations. They have also been tested for the protection of human and property resources. One of the applications of these robotic systems is in Fire Prevention and Control. The automatic fire fighting system is constructed using different control system for various purposes such as fire detection, driving unit, and fire extinguish and GSM module for notification about fire to owner. The control system is constructed using microcontroller AT mega328, infrared sensor ultrasonic sensor and solenoid actuator. The system used an Atmega328p microcontroller to automate the detection of fire, abating of the fire by using extinguisher, and notification about the fire breakout.

**Keywords:** microcontroller, Atmega328, sensors, fire extinguisher

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## 1. INTRODUCTION

Automatic control is the controlling process without human interaction. Now a days there are many processes which need to be automated in industrial as well as domestic environment. The biggest benefit of automation is that it saves labor; however, it is also used to save energy and materials and to improve quality, accuracy and precision. Automation can be achieved by various means including mechanical, hydraulic, pneumatic, electrical, electronic devices and computers, usually in combination. Over the course of years, since 1960s, the concept of robots and integrated systems has advanced exponentially such that these systems are now capable of independent operation.

A robot is an integration of technology related to mechanical, electronics and software. It represents the physical manifestation of information technology - a versatile machine which can carry out the instructions of an intelligent system, e.g. computer. Industry has benefited drastically from the expanse of a robotic work force. Automated machines have taken over the duties of dangerous and mundane jobs from humans, allowing greater productivity. The use of robotic systems is not limited to industry. Nowadays robotic systems are used in many areas such as military, agriculture, and many household applications such as automatic washing machines, automatic vacuum cleaners, and automatic dish Washers, automatic garbage disposal system etc. The firefighting is one of the process which can be automated for industrial and domestic purpose.

In India, it is estimate that about 42 females and 21 males die every day due to fire. According to the statistics released by the National Crime Records Bureau, fire accounts for about 5.9% (23, 281) of the total deaths reported in the year 2012. Fire accounts for 8.45% of the

overall rankings of risk where electric defaults are regarded are the major cause of fire.

The fire is extinguished commonly by water. Water extinguishes a fire by cooling, which removes heat because of water's ability to absorb massive amounts of heat as it converts to water vapor. Another extinguishing method is chemical flame inhibition. This can be accomplished by applying dry chemical or halogenated agents that interrupt the chemical chain reaction and stop flaming. This method is effective on gas and liquid fuel; because, they must have flame to burn

The commonly fire extinguishing methods used are not fully automatic as it needs human supervision. These methods are not much effective to abate and extinguish electrical fires which are a main concern in household fires today.

The purpose of present study is to design and fabricated an automatic fire extinguishing system which is capable to extinguish fire due to electric short circuit for house hold application. For this purpose a literature review has been carried out on the work done by previous researchers in regard to automation of firefighting system.

## 2. LITEARATURE REVIEW

A.James Xu, Warwick Coombe .etal [1] (2009) have designed an experimental model specifically for industrial purpose. In this study, they constructed a robotic system. The robotic system is designed to run automatically, avoid any obstacles, find and track two flames (candle light), and extinguish fire. For this purpose, the fire-fighting robot is divided into 4 major parts namely; master controller, motors, proximity control, and fire detection. The PIC16F877A master microcontroller was used which co-ordinates and regulates the motion and signals form motors,



proximity sensors, and fire detectors. Servo motors are used to control the motion of the robot. For obstacle detection and collision prevention, opt electric sensor GP2D120 was used. 6 panels of IR sensors were used for 360° fire detection. A motor driven fan was used as a fire extinguishing medium. The fire detection units activates the microcontroller which then drives the robot towards the fire source, meanwhile preventing collision with the surrounding obstacles present, if any. Once within the effective zone, the fan was driven to put out the fire.

B.Hesham Ibrahim Darwish [2] (2012) have designed and developed an experimental model for study and competition purpose. In this study, the author has designed a fully automatic to microcontroller which develops the warning signal for robot to initiate the action. Temperature sensors & robot are interconnected with the help of Radio Frequency Transmitter & Receiver through two microcontrollers. Water is used as an extinguish medium. This system is used to extinguish a lit candle inside a house. For this purpose, the robotic system designed was a 4-wheel carbon fiber chassis. Ultrasonic sensors, heat and light sensors were used to detect obstacles and fire. DC motors and Servo motor were used to control robot movements using respective motor controllers. Automatic fan linked to a motor was used for extinguishing the candle flame most effectively. Arduino was used as the microcontroller based on Fuzzy Logic approach. The main function of the system was to detect, find and extinguish the flame of the candle in the shortest possible time

C. V. Kale, AbilashDhumatkar et.al [3] (2015) have constructed an experimental model for industrial purposes. They use electrical thermostat technology for controlling the fire. They have used synchronized the equipment using thermostat sensor, water jet, wireless remote, and wireless android device Wi-Fi enabled Camera. The robot can be controlled remotely & there was live video buffering. Thermostat is used to measure and maintain the temperature of any system. This was achieved by turning on or off the heating/cooling device. Water tank has been used which was operated by a pump. Wireless device was used to control the robot from a faraway place. android device Wi-Fi operated camera has been used for video feedback to the firefighting team. The main objective is to fabricate a fire-fighting robot which is Automatic Fire Fighting Robotic System coordinated with the firefighting team by giving live feedback & immediately extinguish the fire before it spreads out.

D Prof. V. Kale, AbilashDhumatkar, et.al [4] (2015) Authors have constructed an experimental model for industrial purposes. They use electrical thermostat technology for controlling the fire. They have synchronized

the equipment using thermostat sensor, water jet, wireless remote, and wireless android device Wi-Fi enabled Camera. The robot is controlled remotely & there was live video buffering. Thermostat is used to measure and maintain the temperature of any system. This was achieved by turning on or off the heating/cooling device. Water tank has been used which was operated by a pump. Wireless device was used to control the robot from a faraway place. An android device Wi-Fi operated camera has been used for video feedback to the firefighting team. The main objective is to manufacture a fire-fighting robot which will Automatic Fire Fighting Robotic System coordinate with the firefighting team by giving live feedback & immediately extinguish the fire before it spreads out.

### ***1. Summary of literature review***

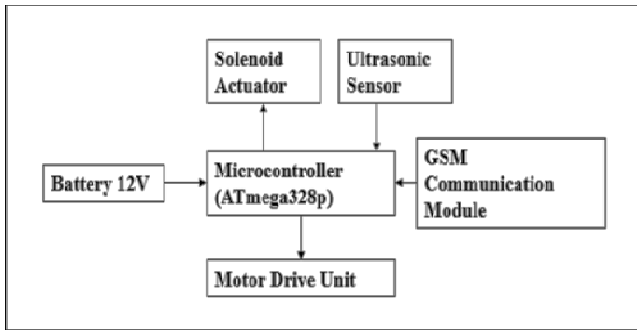
The literature study shows most of the researchers attempted for automation of firefighting system. The design of control system has been finalized from the literature study. The next section deals with design and component of control system.

### ***2. Design and components***

In order to design and develop a control system, testing circuits and setups of different modules have been constructed. A thorough literature survey is conducted and the work carried out by other researchers have been studied. After going through previous literature papers, a design has been prepared. The basic block diagram, construction, and working of the different setups has been discussed in the subsections below along with the list of components required.

The system consist of different unit such as obstacle detection unit, fire and its location identification unit, actuating mechanism to extinguish fire and notification module. The obstacle detection is done by ultrasonic sensor. The ultrasonic sensor has one transmitter and one receiver, which can transmit and receive ultrasonic waves which is reflected by obstacle. The ultrasonic sensor gives signal to motor driving unit. The motor driving unit is able to give different motions such as forward motion, reverse motion, zero left turning and zero right turning. The above four different motion of motor are able to turn and move the entire assembly of firefighting robot. The fire detection is done by infrared thermometer which is able to detect fire based on temperature of object. The signal of infrared sensors given to microcontroller which further activate the solenoid actuator. As the fire detected by infrared sensor, the solenoid actuator actuates and open container and spray on fire. Figure 3.1 shows the block diagram of the control system for automatic firefighting robotic system.

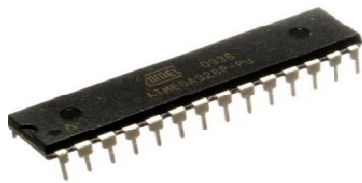
The various components used in the construction and development of the firefighting robot is discussed below.



**Fig. 3.1 Basic Block Diagram of Control System**

### ***I. Atmega328p chipset***

Atmega328p, as shown in the figure 3.2, is the microcontroller is used to control the communication of signals between various peripheral components. It also helps in integrating all the different electronic, electrical, and mechanical components in the system.



**Fig. 3.2 ATmega 328p Microcontroller Chipset**

### ***II. Motors***

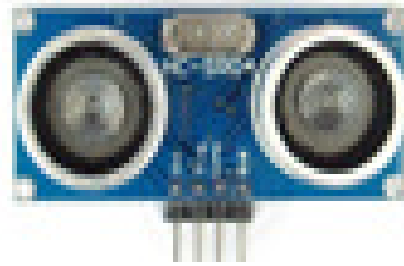
Four 12V DC motors are used to provide the forward, reverse, zero left, and zero right motion to the system. The motor provides a torque of 2 kgf-cm at 30 RPM for the effective motion of the robotic system. A DC motor is shown in Figure 3.3



**Fig. 3.3 D.C. Motor**

### ***III. Ultrasonic sensor***

Ultrasonic sensor is a device which is used to measure the distance between two surfaces by transmitting a pulse from its trigger port. The pulse on reflection from the surface is incident on echo port and based on the speed of the pulse, the distance is calculated. The figure 3.4 shows the ultrasonic sensor.



**Fig. 3.4 ultrasonic sensor**

### ***.IV. Infrared Thermometer MLX90614***

The MLX90614 is a laser guided, non-contact infrared thermometer. The accuracy of this thermometer is higher due to laser guided technology. This sensor is used because of better accuracy in temperature measurement and high spot to distance ratio of 13:1.



**Fig.3.5 Infrared thermometer**

### ***V. Extinguisher Spray Canister***

It is a vessel containing pressurized extinguishing medium, in the form of foam. It spray the extinguishing foam when the top button is pressed. A spray type fire extinguisher, as shown in Figure 3.6, is a portable and light-weight device. This type of extinguishers are perfect for a small scale fire extinguishing system. The operating pressure of this type of extinguisher is the range 10-15 bar. The throw of extinguishing medium achieved is up to 6 feet.



**Fig. 3.6 Fire Stop Extinguisher Canister**

### ***VI. Solenoid Actuator***

The solenoid actuator as shown in the figure 3.7 is used as the actuating mechanism for the extinguisher spray canister. The solenoid actuator operates at 12V DC supply and gives a 3kgf force on the spray canister.



**Fig. 3.7 Solenoid actuator**

### **VII. GSM Module**

Global System for Mobile communication or GSM communication module is used to establish communication between a computer and GSM-GPRS system. The GSM module is incorporated to notify the house owner and the concerned authorities about the outbreak of fire in the house. The GSM module used is shown in the figure 3.8.



**Fig. 3.8 GSM Module**

### **VIII. Standard set of wheels**

Wheels are the mechanical components that help in physically driving the systems on a ground surface. The wheels of size diameter 40 cm and width 10 cm have been utilized for the effective traction on the floor and uniform load distribution. The wheels are shown in Figure 3.9.



**Fig. 3.9 Wheels**

## **3. RESULTS AND DISCUSSION**

All the circuit connections of the various sensors were done on a general purpose Printed Circuit Board. A Marine Plywood chassis is constructed using a basic judgment and trial-and-error method. A mild steel frame is constructed to carry the extinguisher canister, solenoid actuator. The heat sensor is also mounted on the top of the mild steel frame. The ultrasonic sensor was installed on the front, wooden cross beams. These cross beams are constructed at the lower part of the wooden chassis. A platform is also constructed inside the chassis. The PCB or Printed Circuit Board is installed on the middle platform. The GSM module is mounted on the PCB itself. A 12V DC battery is also installed on the middle platform of the chassis. Four DC motors were attached to the chassis. The location of the motors is taken to be the end of the two cross beams attached to the chassis. The final fabricated model of the automatic fire fighting robotic system achieved is shown in Figure 4.1.



**Fig. 4.1 Automatic Fire Fighting Robotic System Model**

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- Hesham Ibrahim Darwish, 'Developing a Fire-Fighting Robot', Trinity College Competition, June 2012.
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# Robot Adsorbing Oil Spills Using Natural Nano Particles

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**Abstract:** In an era of increasing environmental concern, oil pollution arising either from marine accidents or from routine ship operations (tanker loading and unloading, etc.) is a major threat for the marine environment. Maritime transport of oil and other hazardous goods has a higher risk since the consequences of pollution are often catastrophic. The average quantity of ship-generated oil that ends up in the sea exceeds 350, 000 tonnes per year. When an oil spill occurs, either in open or confined sea, the ecological damage on the local ecosystem could be huge and irreversible. Birds, sea mammals, fish and several marine invertebrate species are among the groups most impacted, and in some cases the whole food chain is affected.

In view of the above, there is a pressing need for continuous refinement of the existing means and the development and implementation of new technologies with help of Robotics for oil spill combating. To minimise the adverse environmental effects of an oil spill, research should focus to devise technologies that are able to confront the oil, aiming at its actual removal when this is still floating at sea. Towards these directions, in this paper we present a novel concept for effective oil spill confrontation which is based on autonomous robotic systems.

This paper shows the behaviour of a robot floating concept for the effective confrontation of oil spills. It describes a robotic unit of high-power autonomy that adsorbs oil over water surface with the help of Nano-particle and is able to recover oil from Nano-material with the help of magnetic field. A prototype model of robot with constraint design of floating and assembly of different parts inside it has been made with the help of 3D printing for above investigation. The domain of 'robotics' is undergoing a major transformation in dimension as well as scope. Recent Research in various disciplines of technology has revolutionized this domain at an incredible pace far beyond the contemporary state of the art. In this review, we present modern methods of elimination of oil spills using nanotechnology-based techniques.

**Keywords:** Autonomous Robot, Nano-particle, oil spill, water cleaning, oil recovery.

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## 1. INTRODUCTION

During oil extraction and processing (especially in accidental situations), barely separated oil and water mixtures appear, representing serious problems for the environment. In the sea, oil can be present in different migration forms, such as surface films (slicks), water-in-oil and oil-in-water emulsions, oil aggregates and lumps, in dissolved forms. In case of the cold environment, especially evaporation, dissolution and biodegradation of oil are extremely slow. In wintery conditions, cold water affects highly the oil viscosity, making it very thick and sticky. It also contributes to forming of the oil lumps.

In case of oil spills in the ocean, disorder to marine ecology (sea birds, mammals, algae, coral, sea grass etc.) can be caused, beside the health hazards to the human population located in nearby coastal zones. Moreover, the economic loss suffered by oil companies resulting from oil-spillage is enormous. Numerous solutions have been proposed for dealing with the problem of oil spills. These include use of microorganisms to digest the oil, mechanical means like

skimmers, booms, pumps, mechanical separators, etc., sorbents to remove oil from water through adsorption and/or absorption and use of chemical dispersants like detergents etc. There have been many major oil spills incidences in recent years releasing large quantity of oil in sea, and causing fatalities to marine and human life and huge economic losses in terms of oil wastage. Once spilled oil reaches to the shore, it is difficult to recover it effectively. The efforts in cleaning oil spill over water surface cost billions of dollars which goes in vain as the result after cleaning are not very effective.

Nanotechnology-based methods for removal of oil in petroleum spills and its separation from water are discussed in this review with the help of robot. In addition to classic methods of oil removal, the "Nano"- techniques are being currently developed like carbon nano-tubes, sponges, aerogels and nano-composites, metal and non-metal nano-structured oxides, nitrides, salts, and zeolites. Some of these nano-materials can be prepared by "greener" methods at lower costs and without damage to the environment. We

have use biologically synthesized nano-particles which is an important aspect in nano-technology as well as plant biotechnology. Syntheses of silver nano-particles were synthesized by using aqueous leaves extract of *Leucaena leucocephala* L. from green synthesis method. Simplicity of fabrication of Robot, cost reduction for making Nano-particles, and commercial availability of applied Nano-materials are main objectives of current investigations.

This work presents a method for identifying and locating oil waste floating on sea water surface by using low cost Bio-sensor before the cleaning robot starts navigation. A Bio-sensor in collaboration with GPS unit is utilized as a waste detector heading into water surface and scanning for floating oil spills. As the Robot floats over sea surface, acoustic wave device is used to keep animals away from the polluted source and expels them during the cleaning process.

## 2. LITERATUREREVIEW

In history there are many more incidents where oil-spill cleaning cost was very high and it was not effective. For instance, the most expensive oil spill in history is the one caused by Exxon Valdez in Alaska in 1989, where clean-up alone cost about USD 2.5 billion and total costs (including fines, penalties and claims settlements) are estimated at USD 9.5 billion. Despite the effort and resources allocated, the clean-up operation had little success and the whole incident led to a major environmental disaster. It is impossible to avoid accidents but preventive measures may reduce the frequency of spills. Till date, the prevailing oil spill counter-measures vary from mechanical and chemical methods, to the use of absorbents, oil burning and bioremediation.

Surface cleaning robots on lake, pond, or reservoirs which are motion controlled and has autonomous driving can be technological solution for above problem. Motion of the robot can be represented by hydrodynamic model and maneuver ability performance. The asymptotic stabilization control can be validated for motion control of the surface robot. As for autonomous driving, algorithm with obstacle avoidance is implemented by using ultrasonic sensors. Later, a low cost robot structure design was presented and simulation of multi robot system for oil spills cleaning is proposed. The strategy of waste removal in a large area was presented whereas waste is assumed to be randomly distributed but waste position is known.

For pollutions in general, two main treatment routes are known, adsorptive and reactive. In case of oil contaminated water, conventional techniques are not frequently adequate to solve the problem of massive oil spills. In recent years, nanotechnology has emerged as a potential source of novel solutions to many of the world's outstanding problems. Although the application of nanotechnology for oil spill

clean-up is still in its nascent stage, it offers great promise for the future. In the last 5 years, there has been particularly growing interest worldwide in exploring ways of finding suitable solutions to clean up oil spills through use of Nano materials.

In particular, the Nano-porous sorbents, namely thermally exfoliated graphite oxide (TEGO), CF₃-functionalized aerogels and carbon nanotube sponges have outstanding oil absorption capacities, among other adsorbents. Briefly, the description of nano materials for oil spill clean-up is as follows:

- Aerogels (hydrophobic aerogel, CF₃-functionalized silica aerogel, aeroclays, etc.).
- Nano-dispersants (micelles forming colloidal solution of bio based chemicals).
- Membranes (on the basis of manganese oxide nanowires).
- Foams and meshes (superhydrophobic and superleophilic).
- Filters/pads (oil repellent/hydrophilic cotton filter, superhydrophobic and superleophilic filter paper).
- Carbon nanostructures (graphene worms, CNTs sponges, vertically aligned CNT membranes, Recam).

The nascent area of the treatment of oil spills with nano materials possesses a series of successful attempt and has advantages. However, at the same time, there are certain risks associated with their use. The nano materials may have negative impact on human health when these nanoparticles are inhaled, absorbed through skin, or ingested. There is also some scientific evidence, showing that the nanoparticles can travel through the food chain from smaller to larger organisms.

## 3. THE PROPOSED METHOD FOR ADSORBING OIL SPILLS USING NATURAL NANO PARTICLES

To gather information on sea surface and to clean oil spill, we rely on underwater robots to do that hard work. There are two kinds of underwater robots: remotely operated vehicles and autonomous underwater vehicles. Remotely operated vehicles (or ROVs) are connected to a cable that allows a human to control the robot from a ship or boat on the ocean surface or from within the robot. Autonomous underwater vehicles (or AUVs) are controlled by computers on Robot, and can operate without being connected to the surface. Because both ROV and AUV robots contain computers and electronic equipment, underwater robots need to be waterproof.

Aquatic robots could float like tiny insects on the surface of the water with the help of Surface tension, the force that also resists surface ruptures. That is why, for example, a thin sewing needle can be placed on a slip of tissue paper

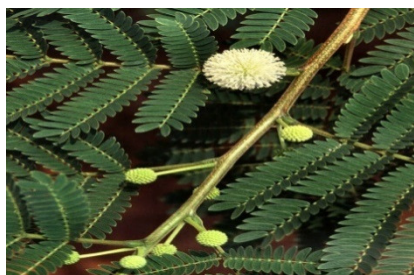


on water, and the needle will stay afloat even after the tissue becomes waterlogged and sinks. This experiment works better if the needle has a hydrophobic—or water repellent—coating such as Teflon.

The GPS-equipped floating robots demonstrated the next generation of water monitoring technology, promising to transform the way mechanical system used to do it.

### 3.1 Identification of the Nano-Particles

**1:** Biosynthesis of nano particles, its characterization and applications of biologically synthesized nano particles is an important aspect in nanotechnology as well as plant biotechnology . In the present study, syntheses of silver nanoparticles were synthesized by using aqueous leaves extract of *Leucaenaleucocephala* Leaves shown in fig.1 from green synthesis method. This aqueous extract of the leaves of *Leucaenaleucocephala* L. is used as bio-reducing and stabilizing agent. The characteristic of synthesized silver nanoparticles were studied using UV-Visible spectrophotometer (UV-Vis), Fourier transform infra-red spectroscopy (FT-IR), Energy-dispersive x-ray spectroscopy (EDX), Scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis shows the average particle size is about 20.18 nm. This rapid green synthesis method indicates that it is simple, expensive, eco-friendly and convenient method than other chemical and physical methods.



**Fig. 1** Leaves of *Leucaenaleucocephala*L.

### 2: Process of Synthesis

- Practical Collection of Materials i.e. Fresh leaves of *Leucaenaleucocephala* L.
- Preparation of *Leucaenaleucocephala*L. Leaves Extract
- Biosynthesis of Silver Nanoparticles Using *Leucaenaleucocephala* L. Leaf Extract
- Characterization of the Synthesized Silver Nanoparticles
- Finally nanoparticle are produced which are embedded in honey comb structure for operation.

**3:** Practical implementation of nanotechnology for oil spill remediation demands that the nanomaterials in the form of nanoparticles/ foams/sponges etc. be suitably engineered or

packaged to facilitate their application. One example is TEGO, which is a powdery material that has to be contained in large porous sacks made from polypropylene or polyethylene fabric or porous film. Alternatively TEGO can be co-processed with a polymer binder in the form of a foam sheet. This open cell structure of the foam allows contact between the oil and the TEGO surfaces. The advantage of this system is that the absorbent system can be rolled for storage. Another practical example is MIT's sea-swarm robot incorporating oil absorbing nanowire mesh. It is capable of autonomously navigating the surface of the ocean to collect surface oil and process it on site.

There are several important things you must consider when building a robot boat. There are weight issues, balance issues, hydrodynamics, waterproofing, the actuator, and sensing problems. Weight is important when loading your robot boat with various equipment. It needs motors, batteries, sensors, controllers, it all adds up.

### 3.2 Robot Component Designing, Manufacturing and Description

#### 1. Bottom part

This is manufactured with the help of 3D Printer. Thermoplastics used in 3D printing are high performance, engineering-grade materials which exhibit many of the same properties of injection moulded plastics.

3D printing thermoplastics include polycarbonate (PC), acrylonitrile butadiene styrene (ABS), , PP copolymer, acrylonitrile styrene acrylate (ASA) and even ULTEM. These materials are typically manufactured using Fused Deposition Modelling (FDM) 3D printing technologies. FDM is an additive manufacturing process which extrudes molten materials layer by layer to result in a final product.



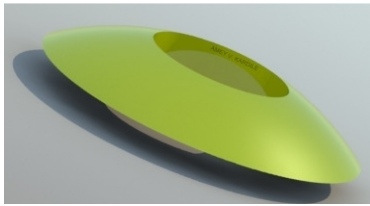
**Fig. 2** Robot Base

It provides the space for the other components to rest inside it and it contains all the assembly elements which helps for the cleaning of the oil spill and/or for functioning of the whole system as shown in Fig.2.

It also provides large surface area for buoyancy and keeps the robot stable in sea environment.

## 2. Top part

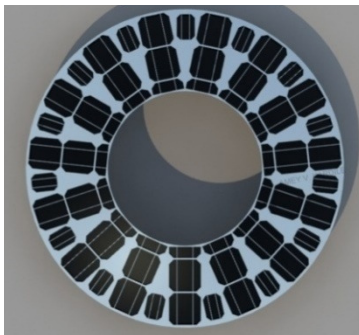
The manufacturing process for this part is same as the above part as it is the same body made from the 3D printing process with same mechanical properties.



**Fig. 3. Robot Top**

It also fix the container position and kept it stable on the robot as shown in fig.3.

Top part provides the area for solar energy production and/or resting the solar panel on it as shown in fig.4.

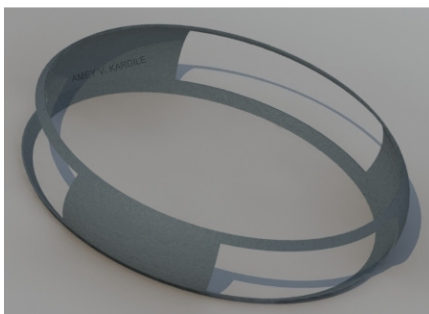


**Fig. 4. Robot Top**

## 3. Rubber Connector For Top and Bottom Part Of Robot

This rubber is mainly used to fix the robotic part on its place firmly & provide flexible support and prevents the striking of wave on the rim part and protect them from wear and tear as shown in fig.5.

The material used for this rubber is Hypalon, Which have high strength, good corrosion resistance, Low wear and tear and can withstand in adverse environmental condition as well as low elongation property.

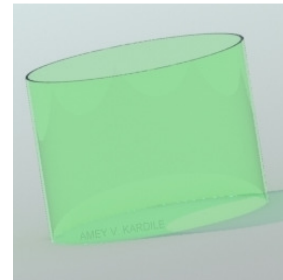


**Fig. 5. Rubber Connector**

## 4. Container

This used to store the oil after the separation from water.

This mainly contains the 4 parts as shown in fig.6, 7, 8&9.



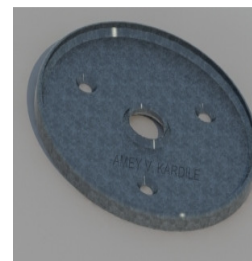
**Fig. 6 .Container body**



**Fig. 7. Honeycomb Nano particle structure**



**Fig. 8. Container top**

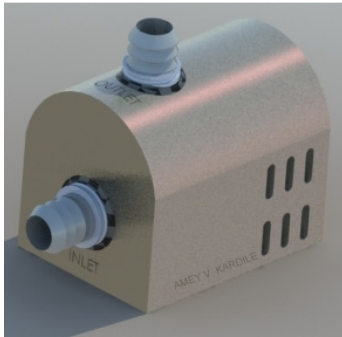


**Fig. 9. Container bottom**

## 5. Pumping Device (oil-water Pump)

- Voltage input = 12 V
- Inlet port fitting =  $\frac{1}{2}$ " = 1.5 cm
- Outlet port fitting =  $\frac{1}{2}$ " = 1.5 cm

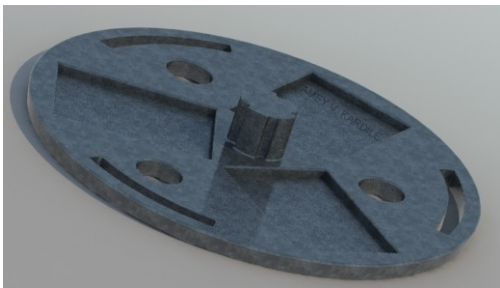
- Power = 60 Watt as shown in fig.10.



**Fig.10 Pump**

#### **6. Pump Mounting plate**

This plate is used for mounting the pump below the container on specific distance. The material for manufacturing this plate is S –glass fibre which have high tensile strength and good resistance property for marine environment as shown in fig.11

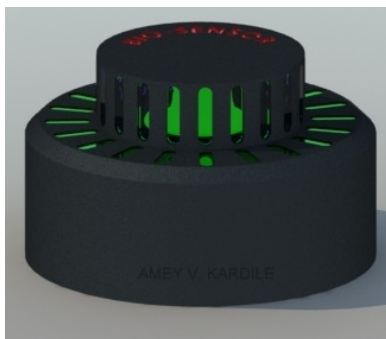


**Fig.11 Pump**

#### **7. Bio-sensor**

For automatic detection of the oil spillage and processing it on sight is done with the help of bio sensor in the collaboration with GPS device as shown in fig.12.

It is mainly based on the principle of detection of the hydrocarbon in the polluted environment & it is available in the market for special purpose only. Many alternative are also available for detection of oil spill.



**Fig. 12. Bio-sensor**

#### **8. Battery**

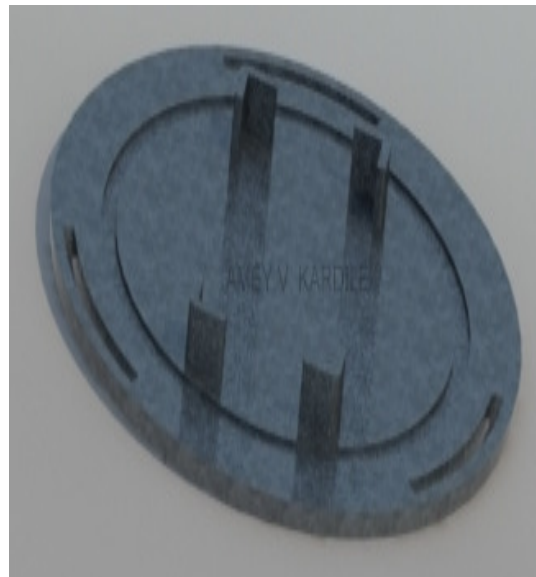
Lithium polymer –LIPO are type of rechargeable battery. LIPO batteries are light weight and hold huge power in a small package. They have high discharge rates to meet the need of the powering robots. LIPO battery are rated as 3.7 volts per cell. So we get in multiples of 3.7v, 7.4v & 11.1v batteries.



**Fig. 13. LIPO Battery**

#### **9. Battery mounting Plate**

This plate is used for mounting the battery on specific distance. The material for manufacturing this plate is S –glass fibre which have high tensile strength and good resistance property for heat transfer as shown in fig.14.

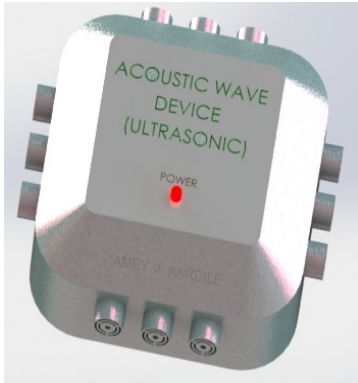


**Fig. 14. Battery mounting plate**

#### **10. Acoustic Wave Device**

As the many animals get harmed due to polluted sea by mean of oil spill. So to keep animals away from the polluted source, and expels them during the cleaning process this device is useful. Range of this device is 5-10 m.

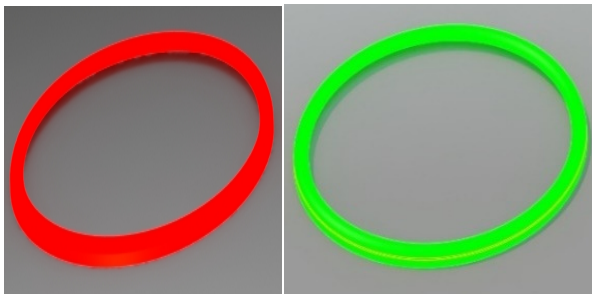




**Fig. 15. Acoustic wave device**

#### 11. GPS & LED Device

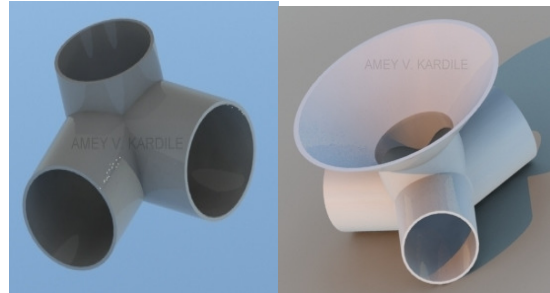
This is mainly used to track the location of the robot in the sea by mean of GPS signals. And the LED indicates the process of cleaning. The red light indicate the cleaning process is going on & green is indication of process completion as shown in fig. 16.



**Fig. 16. GPS and LED**

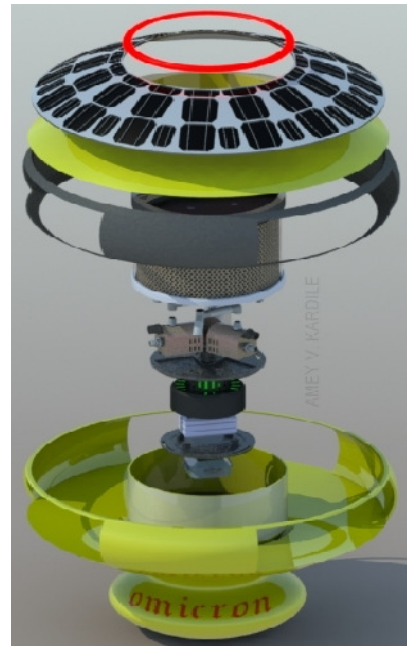
#### 12. Piping System

For transportation of oil & water mixture from pump to the container part piping system is used. This include the 2/1 way connector, Hose, 3/1 way connector. And the connector is made from the PVB material which has the long life, good environmental-corrosion resistance, good elongation property and heat stability.



**Fig.17 2/1 way connector and 3/1 way connector**

#### 4. WORKING OF ROBOT



**Fig.18 Exploded view of ROBOT Assembly**

#### 13. Solar System

To overcome the problem of the power source in the middle of sea we are providing the solar system with advance polycrystalline technology which can produce the maximum energy from the given surface along with the series and parallel combination within the interconnected cell.

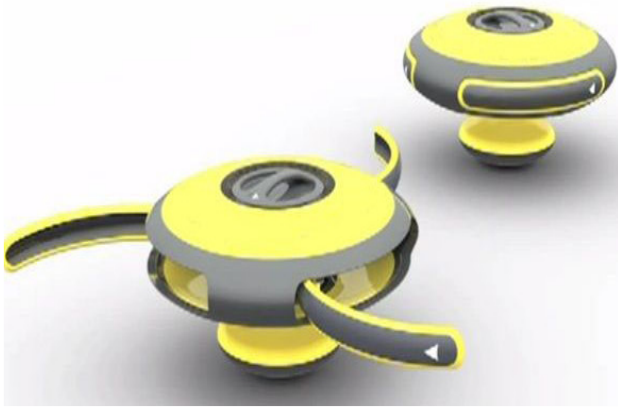
##### Solar Calculation

Voltage output from solar panel

Total Solar Current output = 5A - 15A , Voltage output = 5V- 12V

This is sufficient for the pump to run at most a day/for the working of other electronic components .

Like this we have 3 stripes of panel on our robot = total 45 cells .Thus it is much more sufficient to run 3 pump at a time.



**Fig. 19. 3-D Model of Robot**



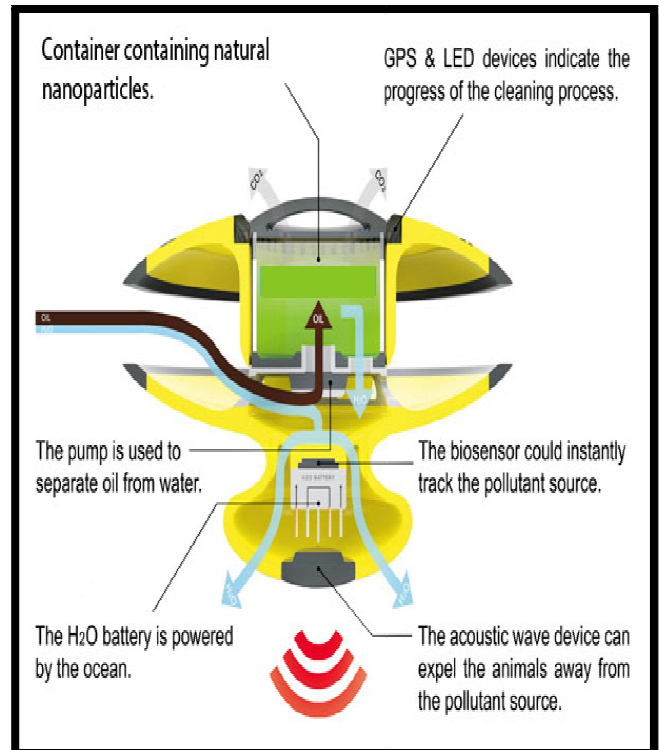
**Fig. 20 Robot operation**

Assembly is done in CAD environment. Figure 18 shows the exploded view of Robot with different parts described above are attached on it.

Working of the whole system i.e. Robot and the Nano technology goes hand in hand.

- Bio-sensor detect the polluted area and the process starts from there by triggering the pump and opening the unidirectional valve to the container.
- Pump takes the oil plus water mixture inside the robot and pump it in the container where the Nano particles made from the green synthesizing method are arranged in the hexagonal honeycomb like structure for maximum adsorption of the oil.
- Due to specific property of nanoparticle i.e. oilophilicity and hydrophobicity only oil remains in the container and water drains out.
- Drained water gets out of the robot from the vents provided for that with uni-directional flow and with some pressure which helps the robot in the propelling on the sea surface and saves the excess use of energy.

- During the cleaning process, acoustic wave device is working to keep the marine animals away from the polluted source by mean of expelling them.
- Solar is provided for green energy production and overcome the excess need of energy required for various electronic devices in built in robot like GPS, LED etc.
- GPS system is for tracking the location of the robot in the sea and LED is for indication of the cleaning process.



**Fig. 21. Working of Prototype Robot**

## 5. ADVANTAGES

- None of the present system gives the recovery of the crude oil
- Eco friendly : as Nano are made by plant leaves
- 100 gm Nano = up to 5 lit oil adsorption capacity
- Nano are reusable by putting them in changing magnetic field.
- Low manufacturing cost
- One time investment and durability of system is up to 8-10 years
- Variable size and capacity
- Innovative solution and unique structure

## 6. CONCLUSION

- a) This paper focuses on the modelling and the control of an Autonomous Vehicle for Intervention (I-AUV). To this aim, an accurate model of the robot has been designed, including the interaction with the fluid.
- b) Discovery of natural nanoparticles with specific properties.
- c) Designing of the robot for the recovery of the oil with varying size and capacity.
- d) Proposed different methodologies for oil recovery using natural phenomenon.
- e) Giving highest oil recovery than the current existing system.
- f) The control system has to make sure that the system can autonomously reach the object to be manipulated and execute the planned task on it.

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# Expert System Methodologies and their Applications in Production Industries

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**Abstract:** This paper surveys expert systems and their applications using a literature review in order to explore the development and applications of ES methodologies. This method classifies and surveys ES methodologies using 7 categories, and correlates their usage and applications within production industries. The methodologies surveyed are: Rule based systems, knowledge based systems, Neural networks, fuzzy expert systems, object oriented methodology, case based reasoning, and system architecture. The ninth section provided addresses a discussion highlighting the scope for further development, along with the limitations of implementation of these expert systems, while the final section is used to conclude this paper.

**Keywords:** Expert systems; Artificial Intelligence; Expert system methodologies; expert systems applications; literature survey

## 1. INTRODUCTION

Expert systems or ES is an integral part of applied artificial intelligence (AI) used extensively in the fields of Production (Production Planning and Control, and Product Management). In layman terms, ES is a human-computer-human interaction that involves expertise, or an extensive task or subject specific knowledge being transferred to a computer by human, wherein this knowledge is stored, and then in the future called upon by users in order to achieve desired outcomes, in the form of advices, suggestions or solutions as and when needed. With the knowledge input in the computer, the computer holds the potential to make logical, mathematical and extremely precise conclusions. Herein, this technology can be used for many sectors of both social and technological life, making it fundamental for problem solving, and aiding the decision process on the whole.

Based on the scope of the multiple articles, and research papers, this paper studies ES methodologies and classifies them in seven categories. They are The methodologies surveyed are: Rule based systems, knowledge based systems, Neural networks, fuzzy expert systems, object oriented methodology, case based reasoning, and system architecture with each methodology addressing different applications and problems in their respective domains.

Within this paper, sections 2-8 address the aforementioned classifications along with their respective applications and provide survey results for the same. Section 9 provides perspective through withheld discussions, addressing the scope for development as well as its forthcoming limitations, while section 10 contains a brief conclusion of this research paper.

## 1. Rule-based systems and their applications

An expert system that contains information received from a human expert, and represents aforementioned information in the form of rules, is known as a rule based expert system. A prominent example of rule based ES is the IF-THEN approach. An appropriate conclusion can be drawn as the rule is used to perform operations on the available data. Inference drawn are basically through computer program that provides a systematic methodology for reasoning, justifying its conclusion based on information available in the rule base or the knowledge base, and then formatting said conclusion.

Rule based systems are used extensively in the production systems, finding significance in the production planning and control. Rule based ES can be used in automobile process planning, hypergraph representations, scheduling strategies, management fraud assessment, material process design, resource utilisation, load scheduling, sensor control, fault diagnostics, geoscience, and knowledge acquisition and representation. These applications are categorised in the following table.

These systems are also capable of developing conclusions from a data set that can be referred to as interpreted data, thus essentially making is a self aware system.

**TABLE 1:- Applications of rule based systems**

1.	PRODUCTION PLANNING
2.	AUTOMOBILE PROCESS PLANNING
3.	MATERIAL PROCESSING DESIGN
4.	SENSOR CONTROL



## 2. Knowledge-based systems and their applications

A knowledge based system (KBS) is a human centred computer program that reasons and uses a knowledge base to solve extremely complex programs. A KBS has four types of sub systems, involving a knowledge base, an inference engine, a knowledge engineering tool, and a specific user interface. KBS generally includes all the organisational information along with the technological and technical applications that help manage all the knowledge assets of an organisation, such as rule-based systems, groupware and database management system.

It is important to note that whilst representing KBS with rules, several advantages are observed. The use of rules implies that domain experts could often define and maintain rules themselves rather than hire a programmer, thus explicitly profiting in acquisition and maintenance. KBS also explicitly allows system to reason about a conclusion, and uses this information to explain this result to users, thus providing a reasoning and explanation after every decision.

Knowledge based systems are often used in engineering failure analysis, in waste management, production management, thermal engineering, framed building evaluation, steel composition design, isokinetic interpretations, plant process control, system design, decision making and learning.

**TABLE 2:- Applications of knowledge based systems**

1.	ENGINEERING FAILURE ANALYSIS
2.	WASTE MANAGEMENT
3.	PRODUCTION MANAGEMENT
4.	THERMAL ENGINEERING
5.	STEEL COMPOSITION DESIGN
6.	PLANT PROCESS CONTROL

### 3. Neural networks and their applications

An artificial neuron network (ANN) is a computational model based on the structure and functions of a biological neural network. This concept is widely used to implement software simulations for massively parallel processes making an essential tool for production departments running simultaneous processes. These ANN's are therefore considered as non linear statistical data modelling tools wherein the complex relationships shared between the inputs and outputs are modelled, or the patterns are found.

Working on the basis of an input output system, an artificial neuron receives inputs that are comparable to the electrochemical impulses the biological neurons received via dendrites from other neurons. The output of the artificial

neuron corresponds to the signals sent by a biological neuron. An artificial signal can therefore be changed comparatively to the physical changes that take place at neural synapses. ANN's generally consist of 3 layers that are inter-connected. The first layer consist of input neurons. These neurons send data onto the second layer, which in turn sends the consequent data to the output neurons in the third layer.

An ANN is used as a random function approximation tool because of its ability to learn from observing data sets. Applications like these help estimate the most cost effective and ideal methods for arriving at possible solutions, whilst defining computing functions and distributions.

Some of the applications implemented by adopting neural networks are the following: fault diagnosis, optimal power flow, inference mechanisms, diagnostic systems, decision making, facility layout design, machine learning, process control, knowledge learning and robotic systems. The methodology of neural networking and their applications are categorised in the following table.

**TABLE 3: Applications of neural networks based systems**

1.	DECISION MAKING
2.	INTERFERENCE MECHANISMS
3.	DIAGONASTIC SYSTEM
4.	MACHINE LEARNING
5.	PROCESS CONTROL
6.	ROBOTIC SYSTEMS

### 4. Fuzzy expert systems and their applications

Developed using the method of uncertainty, fuzzy ES's deal with uncertainty. In simple terms, a fuzzy ES is therefore an ES system that uses fuzzy logic as opposed to Boolean logic. It is therefore a collection of membership functions and rules that are used to reason about data. This technique encourages the process of formal human reasoning, permitting the computer to behave less precisely and logically.

Fuzzy expert systems are typically used when decision making is no longer a black and white, or a true and false scenario. The part of the rule between the "IF" and the "THEN" is the rules _premise_ or _antecedent_. This is a fuzzy logic expression that describes to what degree the rule is applicable. The part of the rule that follows the "THEN" is the rules _conclusion_ or _consequent_. A membership function is thus assigned to each of one or more output variables by the aforementioned rule.

Fuzzy ES is used in fault detection, uncertain reasoning, knowledge integration, online scheduling, machinability data selection.

**TABLE 4: Applications of fuzzy rule based systems**

1.	CONTROL SYSTEMS
2.	FAULT DETECTION
3.	MACHINABILITY DATA SELECTION

### 5. Object-oriented methodology and their applications

Object oriented methodology essentially combines the object data with the specific procedures required to operate on this data into one, whereas the object itself is responsible for the combination of data and the program code. Here, instead of relaying data to procedures directly, a message is sent for an object to perform a procedure by the program. This same message may then be sent to different objects, but each interpretation of the message will differ from another, and the message itself will therein be implemented differently. the object data itself is obtained from other parts of the system, so each object is an independent software building block that can be used in multiple different system without even changing the code.

Some of the many applications of the object oriented methodology are: Industry diagnosis, power system maintenance, knowledge engineering, knowledge learning, knowledge representation and manufacturing information network.

**TABLE 5: Applications of object-oriented methodology based system**

1.	INDUSTRY DIAGNOSIS
2.	MANUFACTURING INFORMATION NETWORK

### 6. Case-based reasoning and their applications

CBR is an adaptive methodology, wherein solutions obtained to solve the previous problems are used to solve new problems. Databases in CBR include part experiences of human experts that are stored and represented as cases. In order to solve future cases under similar parameters. Herein, the system searches the database to find problem characteristics similar to the current one and applies the solution of the old problem case to the new one. Both, successful and unsuccessful solutions are added to the knowledge base. If unsuccessful a reasoning as to why the solution did not work is provided as well.

Some applications implemented by CBR include: Manufacturing process design, knowledge management, fault diagnosis, knowledge modelling, ultrasonic inspection.

**TABLE 6:- Applications of case-based reasoning based systems**

1.	MANUFACTURING PROCESS DESIGN
2.	ULTRASONIC INSPECTION
3.	FAULT DIAGNOSIS

### 7. System architecture and their applications

System architecture provides the user with a general idea of the outlook of the system, and proffers an idea on the implementation of the same. The architecture also provides an understanding of the capabilities of the system functions, system management, a database management system, a specific programming language and helps provide the necessary protocol as well. The user can manipulate and control the system functions on the system architecture, once architecture and implementation are completed.

**TABLE 7: Applications of System architecture**

1.	MATERIAL EVALUATION AND SELECTION
2.	COMPUTER AIDED DESIGNING
3.	ISO SYSTEM IMPLEMENTATION
4.	ERGONOMIC DESIGNING
5.	TRAINING SIMULATOR

### 2. SCOPE OF DEVELOPMENT

- Artificial intelligence and Expert Systems are mutually dependent and interdisciplinary fields of research. Any development in these fields can be achieved by research based development in various other research based fields like machine learning, Computer Aided Manufacturing, Automation in supply chain and logistics, Design for Manufacturing, Process engineering, product designing and more sequential approach to production planning and product engineering.
- Other social sciences methodologies like cognitive science, psychology and human behaviour, and production based problem solving approaches like Human Reliability Analysis (HRA) can be integrated with expert systems. This integration of methodologies and cross- disciplinary research on their interconnection may offer more technologies to investigate ES problems.

### 3. LIMITATIONS

- Most expert systems and simulation systems offer a highly detailed level of task decomposition that may be incompatible with certain Human Reliability Analysis approaches.

- The right potential of Artificial Intelligence and Expert Systems in the field of production can only be harnessed in shop floors and workshops that are highly automated with equipment's like Computer Numeric control machines that can interlinked and accessed through a common computing node. Thus limiting its implementation.
- Adjustments to human error probabilities for dependency based on human action clusters may be artificially inflated when used with a highly detailed level of task decomposition, because there is no dependency calculations.
- Implementation of Artificial Intelligence and Expert Systems require various level of organisational changes that require dedication and initial investment from management as well as workers. This can be time consuming and inability to that change can result in economic losses.
- The generic structure of any expert system is such that it involves setting up of various constant and quantifying stringent parameters so that their effect analysis and problem solving can be done by the expert system. The practical viability of such parameters is limited to large scale industries only since they have the required sources. Thus, making it difficult for small and medium scale industries to implement, which make up as a large section of total manufacturing share for developing countries like India.

#### 4. CONCLUSION

This paper is a literature review based on various survey based research papers and journals discussing the efficacy and application of AI in the field of manufacturing and production engineering through the survey of different ES methodologies. All the pertaining methodologies were assessed based on their implementation, working and application. This paper also addresses the scope for future development through further research in various interrelated fields and it also identifies integration of methodologies used in social sciences as key ways to gain further advancement in this field. Limitations to the use of this technology has also been discussed and it can be concluded that the viability and practicality of implementation of Expert Systems and AI technology can be improved by research in interrelated fields and using a proper combination of above discussed methodologies so as to deal

with the specific application based solution that each of them provides.

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# Comparative Analysis of Healthy and Cracked Ball Bearing Using Vibration Signal, Neural Network with Optimization

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**Abstract:** The purpose of this paper is to review the literature on Health or Condition monitoring methods for detection of damage in different transmission system components. The transmission system is the heart of any industrial rotating machinery hence the health of machine depends on the performance of it. A good Condition Based Maintenance (CBM) reduces downtime, spares inventory, maintenance cost, and safety hazard. It consists of three main steps: data acquisition, data processing and maintenance decision-making.

*This paper outlines the important techniques used in damage detection of bearings using vibration measurement in time and frequency domain. Also it attempts to summarise and review the recent research and developments in diagnostics and prognostics of mechanical systems implementing CBM with emphasis on models, algorithms and technologies for data processing and maintenance decision-making. The main intention of this work is to develop a methodology which will be applicable to the transmission system as a whole and can detect the damage more effectively. The paper concludes with a brief discussion on current practices and possible future trends of CBM as well as challenges and opportunities in this field. In this method features are extracted using fast Fourier transform. By using neural network we obtain our results in which sixteen inputs are used and calculated target value and obtain MSE. Later ANN optimized by using non linear optimize method. To minimize MSE we used genetic algorithm. Obtain best results.*

**Keywords:** Condition monitoring, damage detection, Transmission system, Time-frequency analysis Vibration, back propagation neural network, genetic algorithm

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## 1. INTRODUCTION

All machines with moving parts give rise to sound and vibration. Each machine has a specific vibration signature related to the construction and the state of the machine. The vibration signature of the machine will also change if the state changes. A change in the vibration signature can be used to detect incipient defects before they become critical. This is the basics of many condition monitoring methods. Condition monitoring can save money through increased maintenance efficiency and by reducing the risk of serious accidents by preventing breakdowns. Proper functioning of any machinery in which rolling bearings are used. Material fatigue, improper installation are cause of faults in rolling elements of bearing which cause vibration in it. Many methods are used to detect faults in bearing. Acoustic emissions technique, rough signal analysis, vibration measurements in time and frequency domain. Various neural network are used to diagnosis of rolling bearing faults. Back propagation method is used to diagnostics the faults .but if input parameter are large or system is large then neural network is become complicated for accurate and fast calculation. If number of parameters are high then it's become problematic because it's convergence to local

minima. So non linear optimized technique need to used .in which genetic algorithm is used.

This paper proposes extended condition monitoring method based on the combination of the neural network and genetic algorithm. In the proposed method, faults diagnosis of bearing using Hilbert transform and envelop detection and feature extraction are done by using feed forward neural network and GA, thus the proposed method allows a more reasonable description of the decision making process and reflects the thinking style of human. However,

The aim of the project is to study different faults occurring in rolling elements of bearing, vibration monitoring and envelop detection by using FFT analyzer and using trained neural network which optimized by Genetic algorithm. For classification of features. Fitness function is creating to minimize the error, numbers of hidden layers and number of neurons The rest of this paper is organized as follows. Section 2 briefly reviews the literature on condition monitoring and different methods used to diagnosis machine faults. Section 3 presents the proposed method for machine faults diagnosis. Empirical study is conducted and described in Section 4. Furthermore, discussion is described in section 5. Finally, conclusions are presented in Section 6.



## 2. LITERATURE REVIEW OF THE ENABLERS OF KM ADOPTION IN SC

This faults diagnosis is studied by many authors some of those are mentioned in following paragraph

**TABLE I: Summary of literature review and experts Opinion**

Main criteria	Author	Summary	References
Cepstral analysis	Lelia.nacib, komi midzodzi	Analyzed results show that the proposed method is effective to extract modulating signal and help to detect the early gear fault. For helicopter safety	<i>L.B.Jack, "Genetic algorithms for feature selection in machine condition monitoring with vibration signals, " IEEE, 1999</i>  <i>Neural-network based motor rolling bearing faults diagnosis</i> l, IEEE, 2000
Genetic algorithms and fast kurtogram	Y. Zhang and R. B. Randall	To minimize the error and increase accuracy the wavelet transform is designed. Again it is based on genetic algorithm	Method for intelligent fault diagnosis of rotating machinery, l 2004. Deepak Kumar Panda, Rajat Kumar Bhoi, —Artificial Neural Network Prediction of Material Removal Rate in Electro Discharge Machining, l2005
Monitoring of Fatigue Crack in a High Carbon Steel Rotating Shaft UsingVibration	L.S.Dhamande A.C.Pawar	Experimental test to determine vibration characteristics develop a vibration detection system, and maximize the dynamic range.	A.Thillaivanan, et all, Optimization of operating parameters for EDM process based on the Taguchi Method and Artificial Neural Network, l 2010, International Journal of Engineering Science and Technology, Vol.2(12), 6880-6888. M. Demetgul, M. Unal, "Fault diagnosis on bottle filling plant using genetic-based neural network, "2004, Advances in Engineering Software, vol. 42, pp. 1051-1058
Detection of Fault in Gear Box System using Vibration Analysis Method	A.A. Mohamed, R. Neilson, P. MacConnell, N. C. Renton and W. Deans	By comparing Signals of defective condition with healthy (ok) condition through FFT analyser in which, analysis is carried out with the signal to trace the sidebands of the high frequencies of vibration The validation is done successfully by taking input signal from FFT analyser to MATLAB program..	Attel Manjunath and D. V. Girish, "Defect Detection in Deep Groove Polymer Ball Bearing Using vibration Analysis, "2013, Expert Systems with Applications, Vol 2, 46-48
Nuralnetworks support vector machines with genetic algorithms	B. Samanta	optimization of adaptive filtering of interference in corrupted signal	Van Tung Tran, Bo-Suk Yang, "Multi-step ahead direct prediction for the machine condition prognosis using regression trees and neuro-fuzzy systems, "2004

### 3. EXPERIMENTATION AND METHODOLOGY

#### Experimental set up

**Step 1:** monitor state of machine and to diagnose any defect in condition, to determine the cause of this defect and to predict when failure can be expected.

**Step 2:** Check design of existing machinery. First for healthy rolling element of bearing, In this step, figured out monitoring for healthy rolling element based on the extensive literature review and experimentation.

**Step 3:** It is decided to make planned faults on different element of bearing, such as 0.5mm defect on inner raceway, outer raceway by using EDM. The analysis of vibration of each fault is carried out separately. For that purpose, bearing of same specifications is taken and on each bearing element separate faults are made. The vibration of each faulty bearing element and bearing without any fault is obtained. Thus the signals obtained is analyzed which are valuable for the fault diagnosis.

#### Signal processing

Each bearing has rotational frequency. Defect frequency can be calculated by using geometry of the bearing and it's rotational speed. In this we used 6004 bearing for this inner outer and ball spin frequency can be calculated by using following equation.

$$IDF = N/2 \left( 1 + \frac{R_b}{d_m} \right) \quad (i)$$

Where IDF is inner raceway defect frequency.

$$ORF = N/2 \left( 1 - \frac{R_b}{d_m} \right) \quad (ii)$$

Where ORF is inner raceway defect frequency.

$$BSF = \frac{d_m}{2R_b} * fr * \left( \frac{R_b}{d_m} \right)^2 \quad (iii)$$

Where BSF is ball spin defect frequency

D= external diameter  
Rb = Diameter of roller  
dm = diameter of roller centre  
N= number of roller.

For 6004 bearing N=9, Pitch circle diameter=31 Bore diameter(d) = 20, outer diameter(D) = 42 and shaft frequency fr= 16.66 Hz. For 1000 rpm. Vibration analysis in the frequency domain is used to detect location of defects. But, vibration spectrum of the defective bearing

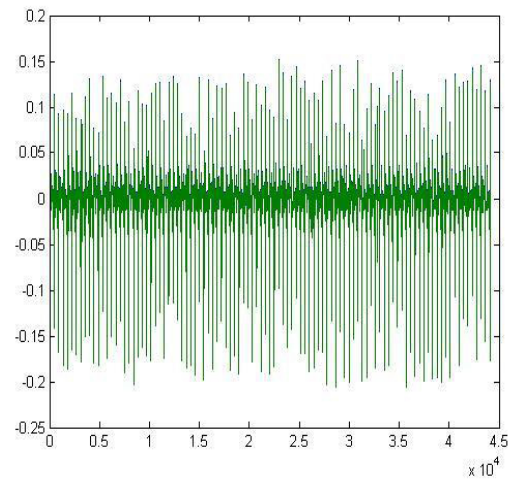
may not be sufficient to identify the origin of defect initially.

#### Step 4 : ANALYSIS OF VIBRATION SIGNAL OF HEALTHY ROLLING BEARING.

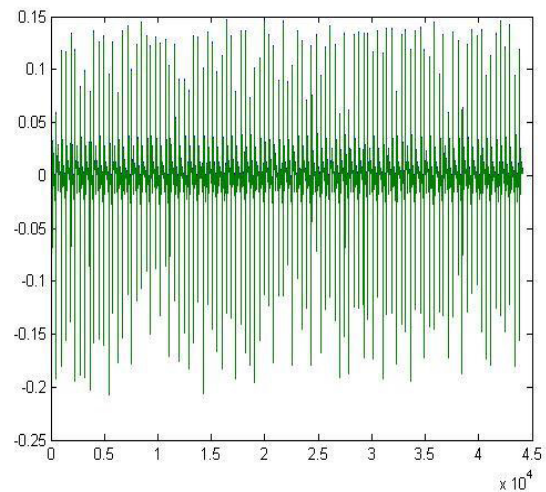
##### i) HEALTHY ROLLING BEARING

When bearing at 200 rpm, 400 rpm, 600 rpm, 800 rpm, and 1000 rpm. And load applied is 3kg.

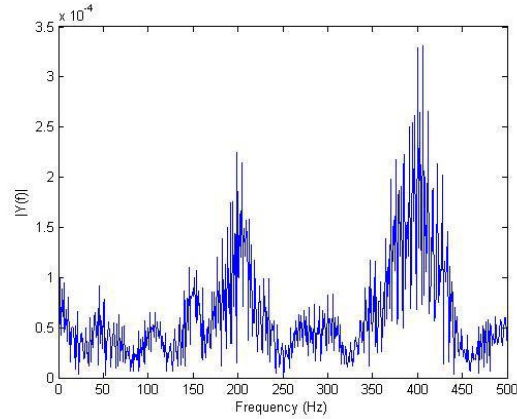
Time domain vibration signal and frequency domain vibration signal of healthy bearing at 3kg load



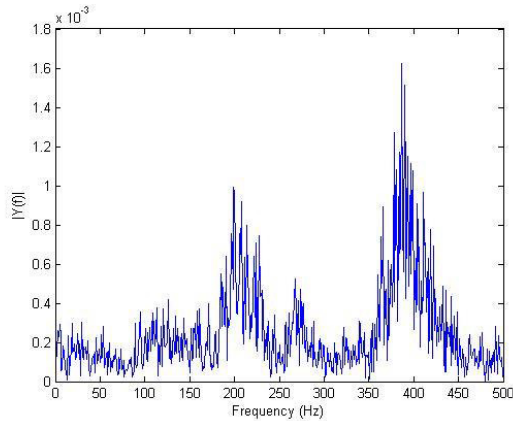
**Fig. 1. Time domain Vibration signal of healthy bearing at 200rpm.**



**Fig. 2. Time domain Vibration signal of healthy bearing at 400rpm**

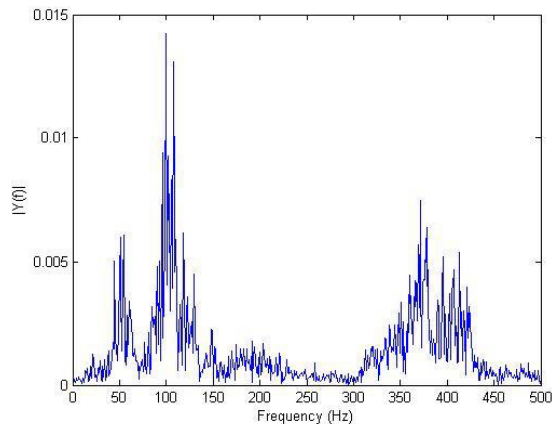


**Fig. 3. Frequency domain Vibration signal of healthy bearing at 200rpm**

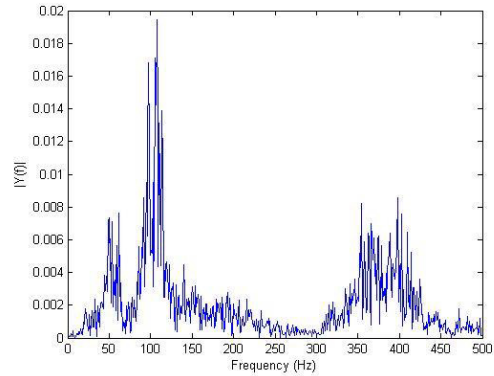


**Fig. 4. Frequency domain Vibration signal of healthy bearing at 400rpm**

when we introduced defect on different rolling bearing by using EDM and again we applied same methodology for defective bearing.



**Fig. 5. Frequency domain Vibration signal of defective gear at 200rpm**



**Fig. 6. Frequency domain Vibration signal of defective gear at 400rpm**

**Step 5:** The envelope detection and FFT methods are applied to raw vibration data. Peak frequency, IRD, ORD, BSF corresponding three harmonics and amplitudes are extracted as features that significantly assist in classifying the faults of the rolling bearing.

#### **Step 6: optimized neural network**

Typical MLP is embedded in layers of the neurons; neurons compute the sum of input variables. Output contained weight matrix, bias generalization of least square algorithm. We have to adjust weight parameter so mean square error will be minimize. In this section, an empirical study is presented to illustrate the application of neural network and optimization of neural network using genetic algorithm.

The developed MLP architecture is computed in Matlab ANN toolbox with its 16 inputs and one output variable. The value of the output indicates classification of the fault. A great deal of GA based study focus on function optimization. In comparison to traditional optimization techniques, GA is effective in solving difficult, discontinuous and noisy functions. In cases where appropriateness function to be optimized is discontinuous, it is infeasible to apply derivation based optimization methods due to impossibility of taking derivative of the function on discontinuous points. However, GA requires no derivations or additional supplementary techniques in solving problems, providing a distinct advantage over traditional methods [1] In an attempt to increase ANN's performance by testing different neuron quantities on different single layers, the architecture of ANN should be determined to minimize the difference between the target and the ANN output.

#### **Problem Description**

The aim of the project is to study different faults occurring in rolling elements of bearing, vibration monitoring and envelop detection by using FFT analyzer and using trained neural network which optimized by Genetic algorithm. For

classification of features. Fitness function is creating to minimize the error, numbers of hidden layers and number of neurons.

#### 4. GA BASED NEURAL NETWORK

In the optimization of GA-based ANN architecture, random built different ANN models are trained with back-propagation algorithm initially and then each ANN Performance is evaluated based on a fitness function. In the vector, transfer function.MLP adjusting weight and bias vector and give desired output. Back propagation MLP is failure of obtaining desired fitness value, parent individuals are selected to create a new generation from the individuals in the population and a new generation is established by

running GA operators in a cycle. This GA cycle is repeated until a desired ANN output value is obtained In the process of forming ANN models, the weights and threshold values are randomly selected; thus ANN models exhibiting similar layer and neuron quantities demonstrate different performance values after training Weight and threshold values of different architectural models tuned by GA optimization are initialized to the values of the reference model before training. At the end of ANN training with the back propagation algorithm, ANN models demonstrate the same gain, weight and threshold values Therefore classification abilities of similar architectures are fixed. It also becomes possible to correctly evaluate the fitness value of individuals in GA optimization in Fig.7

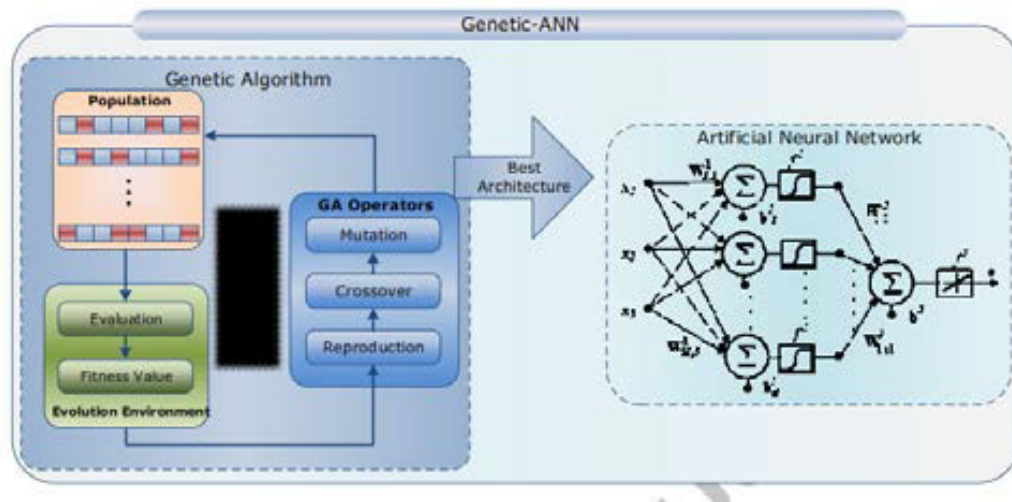


Fig. 7. optimization of neurasl network using genetic algorithm

#### 5. RESULT

TABLE II : Results with optimized neural network

Faults classes	Hidden layer number	neurons	MSE Train	test	Correlation Train test	
healthy	2	10-3	0.0001	0	1	1
Inner race	1	5	0.0098	0.0089	0.99	1
Outer race	2	10-15	0.043	0.045	0.88	1
Ball spin	1	12-7	0.001	0.002	0.98	1

#### 6. DISCUSSION

Extracted features IRD, ORD, BSF, GOOD bearing, peak frequency amplitudes, harmonics, shaft frequency were used as input to the neural network. Output of ANN is inner defect outer race defect ball spin defect location. ANN

obtained MSE and correlation between target data and obtained data. Hidden layer are taken in between 1to 3 and neurons 1 to 15. Healthy bearing given less MSE.

#### 7. CONCLUSION

From the above graph it is observe that amplitude is continuously changing at the frequency of 200 and 400 Hz for healthy bearing and the amplitude of frequency changing at 100 and 380Hz for defective bearing when point defect is introduced, amplitude of frequency changing at 100 and 400 Hz when crack on inner race way portion amplitude of frequency changing at 80 and 380 Hz when when load is applied 3kg. Similarly the graph is plotted when 4kg and 5kg load is applied. Time frequency domain average technique successfully removes the noise from the signal and captures the dynamic of one period of signals. The presence of fault in any rolling element of bearing of the machine give rise to peak in the plot of the time frequency domain average. By using FFT technique it can be predicted that the gear box has some fault but the severity of fault cannot be determined.

In this project paper we detect different faults in bearing using FFT, ANN and Genetic algorithm. By applying signal processing technique and different vibration data by using FFT and envelope detection we can easily detect faults location in machine. GA based optimization increase success 98% Higher correlation and less MSE shows target and obtained values are very close to each other.

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# Design and Implementation of PMBLDC Motor using ANN

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**Abstract:** Brushless direct current (BLDC) motor is being widely used now for industrial and automotive applications. The advantage of these motors is that the removal of brushes leads to eliminate many problems associated with DC motors. This paper mainly presents the simulation of BLDC motor using ANN and its hardware implementation using DSP TMS320F28069. The output of the hall sensor is being fed as input to the controller and the resultant pulses are provided to the switches of voltage source inverter used to run the motor. The entire system consists of PMBLDC Motor, Inverter, DSP and DC Supply.

**Keywords:** Permanent Magnet Brushless DC Motor, Artificial Neural Network, Digital Signal Processor

## 1. INTRODUCTION

Brushed DC motors provide attractive features such as easy speed control and linear torque speed characteristics. The control of DC motor is easier and does not require a complex hardware. But the main disadvantage is that it has got reduced life time due to the presence of brushes [1]. The wear and tear of the brushes causes a reduced reliability of the motor. These reasons to a greater extent reduce the usage of DC motor in the industrial and automotive applications.

Brushless DC motors are more compact, have simpler design, more reliable and have higher efficiency as compared to the DC motors. In addition to this, the BLDC motors also offer greater operating speed and better speed torque characteristics [2]. As the brush commutator assembly is not used in BLDC motors, the maintenance cost is reduced and the life of the motor is increased to a greater extent.

So nowadays, the BLDC application motors have increased widely in many industries due to modern control theory for motor drives and development in power electronic technology. Classical PID controllers due to its simplicity and ease in implementation are commonly used in the industries [3]. The control parameter of the PID controller for a linear system model can be easily determined and they give good performance [4]. However, performance of the PID controller for non-linear system application such as BLDC motor drive, are poor and difficult to determine the controller parameter.

The proposed block diagram for the PMBLDC motor system is as shown Fig.1. The system basically consists of a DC source, a three phase inverter, PMBLDC motor and a DSP controller. The three phase supply to the stator windings of the BLDC motor is provided by the inverter. A sensor based rotor position feedback system is being

implemented for the BLDC motor. This paper puts forth the design and an experimental setup of the system shown in Fig: 1. The four main parts of the BLDC control system are the power converter, controller, sensors and the motor. The power converter is a three phase power semiconductor bridge. The main function of the power converter is to transform power from the DC source to AC so the motor can convert electrical energy to mechanical energy. The sensor is used to determine the rotor position, and it sends this information to the controller. The controller requires feedback information about the rotor position so it can generate pulse width modulation (PWM) signals to power the phases of the semiconductor bridge. The controller uses a PWM modulator to generate signals which drive the power converter. The speed of a BLDC is directly proportional to the voltage, and the applied voltage can be increased or decreased to vary the speed of the motor. In a PWM controller, the PWM duty cycle controls the voltage.

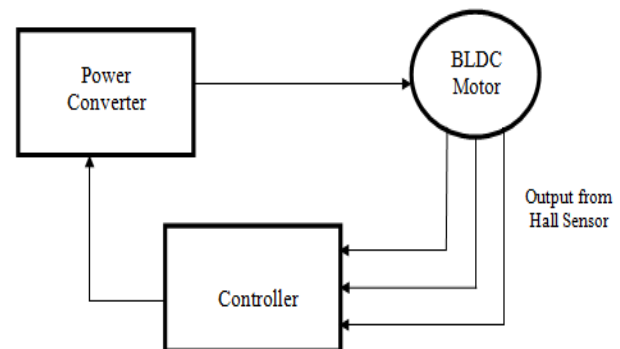


Fig. 1. Block Diagram of the Overall System

## 2. OPERATING PRINCIPLE OF BLDC MOTORS

A brushless dc motor is defined as a permanent synchronous machine with rotor position feedback. The brushless motors are generally controlled using a three



phase power semiconductor bridge. The motor requires a rotor position sensor for starting and for providing proper commutation sequence to turn on the switches in the inverter bridge. Based on the rotor position, the power devices are commutated sequentially every 60 degrees. Instead of commutating the armature current using brushes, electronic commutation is used; hence it is an electronic motor. This eliminates the problems associated with the brushes and the commutator arrangement, such as sparking and wearing out of the commutator brush arrangement

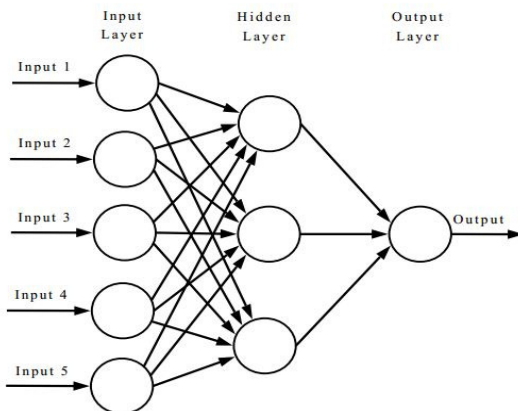
BLDC motor is controlled electronically. The motor is rotated by energizing the stator windings in a particular sequence, and in order to do this it is important to know the rotor position. Rotor position is sensed using Hall Effect sensors which are embedded in the stator. As the rotor magnetic poles pass the sensor, the sensor changes state at the same angular position each time a magnet passes by. Table 1 shows the switching sequence of the BLDC motor.

**TABLE 1: Switching Sequence of BLDC motor.**

Hall A	Hall B	Hall C	Phase A	Phase B	Phase C
0	0	0	DC+	DC-	NC
0	0	1	DC+	NC	DC-
0	1	1	NC	DC+	DC-
1	1	1	DC-	DC+	NC
1	1	0	DC-	NC	DC+
1	0	0	NC	DC-	DC+

### 3. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANN) is a weighted computation system which has numerous processing elements which are interconnected in a particular way in order to perform a specific task [5]. A typical neural network has a number of neurons which form each layer as in Fig.2. The first layer is the input layer the last layer is the output layer and the layers between them is the hidden layer [6].



**Fig. 2. Layers of a Neural Network**

The ANN is basically a weighted computation system where in the inputs are multiplied by their specific weights and then their summation is given to a function that is the transfer function and the output of that specific layer is calculated. The weight of a neuron shows the strength of that input. Thus by adjusting the weights accordingly we can obtain the specific output that is required. As the weight updation is the crucial process in obtaining the output, ANN consists of thousands of neurons, which makes it very difficult to compute the weights by hand. So different algorithms are used to adjust the weights of ANN in order to obtain the desired output from the network. This process of adjusting the weights is called learning or training [7]. A multi-layer network most commonly uses the back-propagation algorithm for the learning process. The desired weight incrementation is carried out by calculating the error between the desired and the actual output.

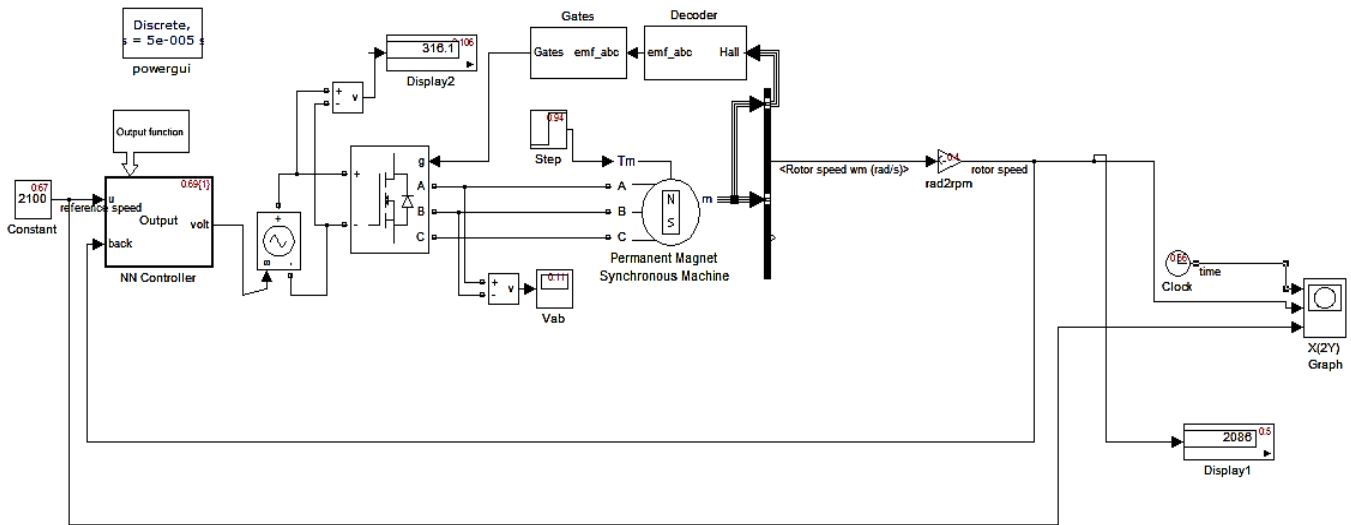
### 4. DIGITAL SIGNAL PROCESSOR

The Digital Signal Processors (DSP) are microprocessors whose architecture has been optimized for real time processing of discrete signals obtained from sampling of continuous quantities. Their architecture has been designed to minimize the period of implementation of processing algorithms such as signal processing. DSP processors offer one of the best combinations of integration, flexibility, efficiency and performance. The drive systems are becoming more and more complex and accordingly, the complexity of control increases. So the design of such systems becomes a difficult task in the absence of efficient controllers. Thus, Digital signal processors (DSP) plays an important role for implementing such complex control since their operating speeds are very high which ensure fast response times. DSPs are also re-programmable, which ensures that changes to the control strategy can easily be made.

The time in which closed loop operation is performed should be very small as compared to the switching time period for accurate working. The TMS320F28069 piccolo control stick is very high speed digital processor with clock frequency 80 MHz which can meet all the requirements. It provides USB connectivity with computer which requires 3.3V or 5V. The PWM pulses are generated from pin GPIO00 to GPIO05. These GPIO outputs are connected to the inverter via buffer circuit.

### 5. SIMULATION RESULTS

The MATLAB-SIMULINK based schematic for the closed loop speed control of 60W PMBLDC motor using Artificial Neural Network is as shown in Fig 3. In this simulation the reference speed is taken to be 2100rpm and the output speed is controlled using ANN such that the output speed of the motor is regulated to the reference value.

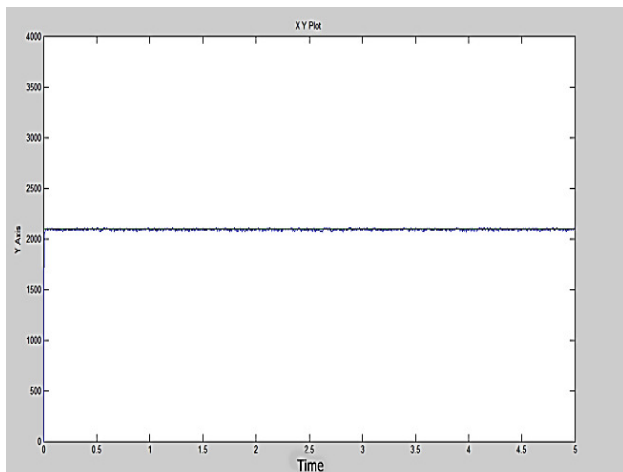


**Fig. 3. Matlab Schematic of Closed loop Control using ANN**

The Back propagation algorithm is basically used for the training of the neural network model. In order to use the back propagation algorithm for any network a set of data with inputs and the corresponding output should be perfectly known. The accuracy of the Back propagation algorithm depends on the value of the learning rate. For faster learning the value should be higher and for accurate learning it should be smaller. For the simulation the learning rate is chosen to be 0.6.

Thus the whole training process is carried out and the weights are updated in such a way that for any input the required output is received.

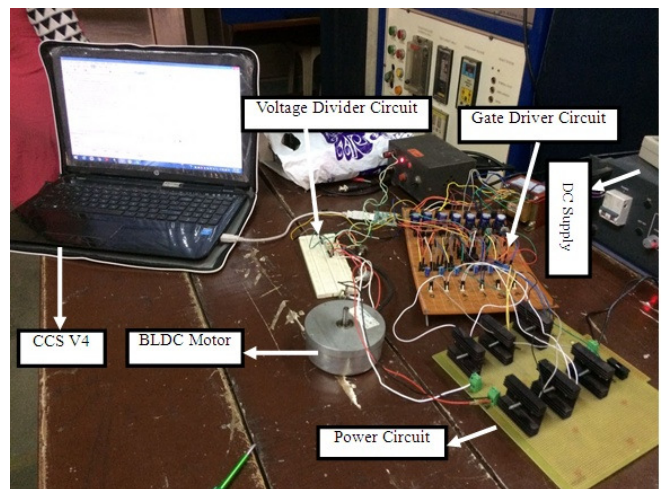
The X-Y graph of reference speed and actual speed is as shown in Fig.4. The reference speed is 2100 and is green in color and the actual speed is blue in color. We can see that reference speed is accurately tracked by the neural network controlled PMBLDC motor.



**Fig. 4. X-Y plot of actual and reference speed.**

## 6. HARDWARE IMPLEMENTATION

The hardware set up of the control circuit of PMBLDC motor is shown in the Fig. 5. At the input of the inverter circuit, we applied a 12 volt DC supply with a maximum operating current of 5 Amperes. The voltage is increased gradually with current setting of 3 ampere and the output voltage started picking up and hence the motor started rotating. In the initial stage the gate pulses to the switches were verified in the DSO by giving a maximum voltage of 15 volt. The PWM pulses are fed to the Driver ICs and further to the MOSFET switches by using the DSP Control Stick TMS320F28069. The Hardware set up consists of Transformer, Auxiliary power supply, Driver and Buffer circuit, Inverter and the Motor.



**Fig. 5. Hardware Set up of PMBLDC motor**

Table 2 gives the hardware specifications for the implemented system which mainly consist of inverter and



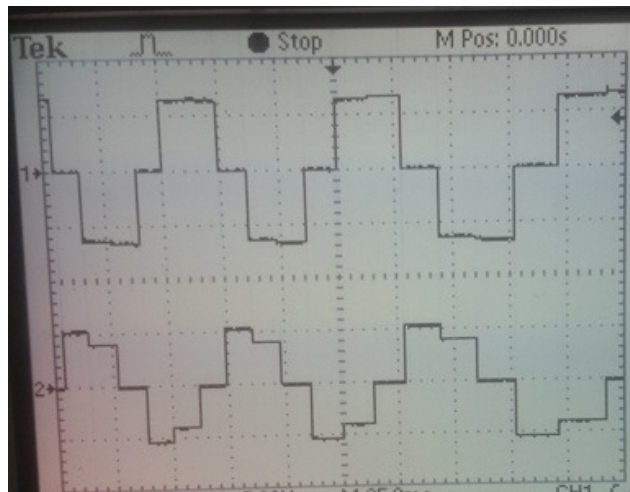
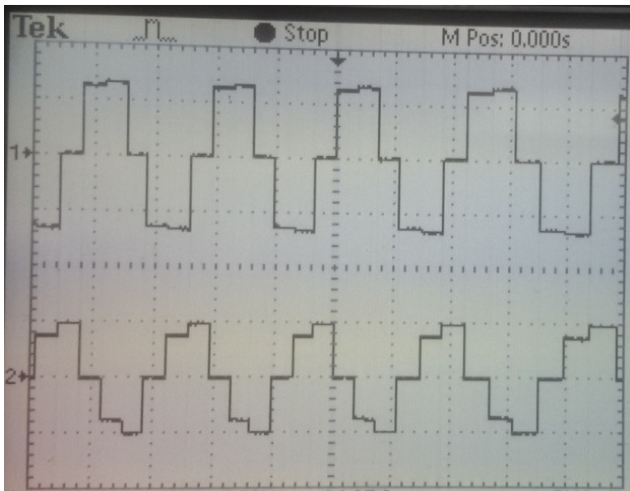
BLDC Motor. In the sensed control of PMBLDC we have run the motor by hall sensor feedback switching scheme for

the inverter using DSP. The performance of the motor is observed in this condition.

**TABLE 2: Hardware Specifications.**

	Component Specification	
	PARAMETERS	VALUES
Power Circuit	MOSFET IRFP260N	200V/50A
PMBLDC	Motor	12V 1500rpm
Driver circuit	Buffer IC	74HC573
	Gate Driver	HCPL3120
	DSP	TMS320F28069

The Fig: 6 shows the output of Voltage Source Inverter. The above results were obtained when the motor was connected in the output of the voltage source inverter. Input voltage of around 12 volts was fed to the inverter using a controlled DC power supply. As we can see in the DSO screen, the waveforms appear to be of PWM output with an output operating frequency of 50 Hz.



**Fig. 6. Output of Voltage Source Inverter**

Thus we can see that we get a square wave at the output of the inverter due to the hall sensor based switching and at one instant of time only two phases out of the three phases conduct due to which the requirement of dead band during the switching of the inverter switches is eliminated.

## 7. CONCLUSION

In this paper we have presented the simulation and hardware results of speed control of PMBLDC motor using ANN. The simulation results show that the ANN controller tracks the reference speed of 2100 rpm. This shows that ANN controller is equally responsive than PID controller and is simple as no tuning is required and entire work is done by the controller itself. For any Motor drive application, ANN based Control is one of the best controllers proposed so far. It allows control of motor only by training the controller with pre-defined sets of input and its corresponding output. From the analysis it is proved that, this strategy of BLDC motor control is simpler to implement than other control methods as it does not require tuning of the controller and even if any of the system parameter changes only new training sets for the system needs to be provided and the controller works effectively. We could successfully run the motor with the signals received by the hall sensors that were processed by the DSP and which in turn were used to switch the inverter.

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SECTION – X

SUSTAINABLE DEVELOPMENT, GREEN  
MANUFACTURING AND WASTE MANAGEMENT

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# Sustainable Manufacturing Assessment Framework: A Case Study

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**Abstract:** Sustainable manufacturing practices aims at minimizing the impacts of manufacturing operations on the environment while optimizing the production efficiency of firms. Today, products are no longer judged by the price but the sustainable initiatives implemented by firms. Efforts to reduce the environmental impacts of manufacturing operations have traditionally been viewed as an obstacle to profitability and efficiency.

The focus of our study is on melting process in foundry. Moreover, the melting process parameters need to be optimized properly. Researchwork propose a sustainability assessment framework for the melting processes so as to improvethem analyzing various sustainability aspects. An exploratory study is conducted to study all the elements ofsustainability evaluations and establishing relationships in between them in order to evaluate their effect onsustainability.

**Keywords:** Sustainable Manufacturing, Sustainability Indicators

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## 1. INTRODUCTION

The creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound. India accounts for about 8–9% of total castings production in the world. The major casting producing regions in the world are depicted. In the year 2009, India's casting production was estimated to be nearly 7.4 million tonnes (MT). India is the second-largest producer of both grey-iron castings as well as steel castings next to China. Indian foundry industry produces various grades of value-added castings as per various international standards. There are approximately 4, 500 foundry units in India out of which 80% can be classified as small-scale units, 15% as medium-scale units, and just 5% as large-sale units. Approximately, 20% of the foundry units have ISO international quality accreditation. There are several foundry clusters in India. Some of the major clusters are Howrah, Coimbatore, Rajkot, Kolhapur, Ahmedabad, Batala, Jalandhar, Ludhiana, Belgaum, Chennai, Agra, Pune, and Vijayawada.

## 2. LITERATURE REVIEW

Industrial economics are increasingly dominated by major concerns about environmental factors, most notably climate change, the shortage of non-renewable energy sources, water and raw material supplies, and commodity price increases. In response to these concerns, national and international authorities have established standards, protocols, regulations, and schemes, such as emissions trading and binding international targets for pollution control and resource efficiency, e.g., the United Nations

Framework Convention on Climate Change (UNFCCC). Manufacturers that do not adapt to these environmental, social and economic changes will be affected in the emerging competitive market for sustainability. Furthermore, the increasing public awareness of the social, environmental, and economic benefits associated with sustainable manufacturing, and of the risks, liabilities, and costs associated with unsustainable practices, represent additional drivers for a more fundamental shift towards sustainability within the manufacturing sector. It is important to note that by adopting the sustainable manufacturing concept, companies have the potential to create new market opportunities and improve their corporate reputation. This in essence supports the development of globally competitive manufacturing businesses and positively impacts on current financial and market performance of such businesses.

Manufacturing involves continual management of a variety of inter-related disciplines and activities, including product design, raw material purchasing, production planning and processes, and environmental compliance. To manage such operations effectively, complex decisions must be made, involving often conflicting requirements. Contrary to traditional manufacturing, which is typically dominated by decisions based on economics only, sustainable manufacturing management is based on a more comprehensive, multi-criteria, decision-making process, which seeks to balance social, Environmental and economic elements of manufacturing. Capable of being washed in low temperatures using environmentally friendly agents (where applicable); Capable of being returned safely to the environment at the end of their useful life. This

research work sustainable assessment framework for melting process and use of three sustainable dimensions and their key parameters.

### 3. IDENTIFICATION OF SUSTAINABLE MANUFACTURING PARAMETERS

Only recently with increase in customer inclination towards sustainability aspects, a largenumber of firms havebegun using environmental, health and safety (EHS), and social indicators.

In this paper, the entire sustainablemanufacturing parameters are identified from literature and divided into threedimensions viz. economic, environmental and social dimensions. These research papers are presented in chronological ascending order. The parameters in each dimension have further been presented in various relevant categories.

#### 3.1 Economic Dimension

A summary of economic parameters identified from literature have been presented in respective categories asfollows:(A) **Manufacturing Cost:** 1 Unit Production Cost; 2 Actual Melting Cost; 3 Idle Cost; 4 Cost of by-product treatment; 5 Governmental Policies; 6 Machine Tool UsageCost. (B) **MeltingPerformance:** 7 Quality of melt; 8Melting Temperature; C) **Production Efficiency:** 9 Production rate; 10 Power required ; 11 Material melting Rate.(D) **Process Improvement:** 12 Process Management; 13 Continuous improvements of existing processes; 14Improvement of material/energy consumption; 15; Performance Measurement.16; Energy efficiency & power consumption 17; Installation & Training cost;18; operational cost; 19 Material Utilization

Table 1 shows the number of articles which have included various economic parameters in referred papers/articles.

**TABLE 1: Economic parameters used by various researchers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Branker and Jeswiet (2012)																			
Chandra (2009)												*	*						
Shivakoti e t al. (2012)	*								*	*	*								

#### 3.2 Environmental Dimension

A summary of environmental parameters identified from literature have been presented in respective categories asfollows:(A) **Water Consumption:** 1 Water Intensity; 2 Consumption of water per unit of output;(B) **Energy Consumption:** 3 Energy Intensity; 4 Energy consumed per unit of output; 5 Renewableproportion of energy consumed;(C) **Types of material:** 6 Materials; 7 Hazardous materials (kg/product); 8 Raw materials (kg/product); 9 Material composition (%); 10 Packaging re-usability (kg/product);11 Packaging recyclability (kg/product); (D) **Waste and Pollution:** 12 Waste Management;13 Weight of

releases into air (GHG Emissions) from production process; 14 Weight oftransfers into disposal from production process (consumables, chips, scraps); 15 Weight of transfers for treatment from production process; 16 Weight of transfers to recycling from production process (scraps); 17 Weightof transfers for energy recovery from production process; 18 Consumables reuse ratio; 19 Weight of transfers tosewage from production process; 20 Pollution impact on ozone layer; 21 Wastage and Spill over during production;22 Life cycle factor, 23Environmental Effect.

Table 2 shows the number of articles which have included various environmental parameters in referredpapers/articles

**TABLE 2: Environmental parameters used by various researchers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Jawahir et al. (2006)					*																	
Mitra and Datta (2013)					*																	
Yucel and Gunay(2013)				*	*																	
Lu et al. (2010)(2012)	*	*			*							*	*	*	*	*		*				
OECD	*			*	*																	
Singh et al. (2007)						*	*	*	*	*	*											

### 3.3 Social Dimension

A summary of social parameters identified from literature have been presented in respective categories as follows: (A) **Health Issues:** 1 Worker Health; 2 Chemical Contamination of working environment; 3 Mist/dust level; 4 Physical Load Index; 5 Noise Level; 6 Health related absenteeism rate; 7 Admitted level of emissions and waste from melting operations. (B) **Safety Issues:** 8 Worker Safety; 9 Exposure to toxic chemicals; 10 Number of occupational accidents; 11 Operator Risk Level; 12

Ergonomic Design of human interface. (C) **Labor Issues:** 13 Labor Relations; 14 Hourly Wages; 15 Working Hours; 16 Workload; 17 Community Engagement; 18 Local Employment, and (D) **Workforce Training:** 19 Training and Education; 20 Average Number of Hours of training per operator; 21 Required Skill Level; 22 Ethical Responsibility 23 Social Impact.

Table 3 shows the number of articles which have included various social parameters in referred papers/articles.

**TABLE 3: Social parameters used by various researchers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lu et al. (2010)(2012)							*																
Zhang and Haapala (2012)							*			*				*	*	*	*	*					
Jawahir et al. (2006)	*						*	*		*		*											
de Araujo and de Oliveira (2012)	*				*		*			*	*		*	*					*	*			

## 4. IMPLICATIONS OF STUDY

1. In light of current sustainable manufacturing frameworks, a huge list of parameters is being proposed and used by various researchers to evaluate sustainability but there is no proper classification for the same and all are in scattered form. This framework tries to capture the realistic parameters and also classifies them in suitable levels resulting in proper hierarchy of sustainable manufacturing parameters.
2. It is also difficult to evaluate and compare the sustainability of various organizations as different organizations use different set of parameters for evaluating the sustainability. With this framework, it will be easier to capture all the realistic parameters and evaluate and compare the sustainable performance of manufacturing organizations.
3. This framework intends to act as base for various sectors of manufacturing which can be used to evaluate their sustainability by finding the importance of each of the parameters amongst various sectors of manufacturing.

## 5. CONCLUSION

Sustainable manufacturing is becoming important for industries considering the increased pressure from market. This paper is focused on developing an integrated

sustainable manufacturing assessment framework which can be used by various manufacturing organizations to assess their sustainability level and enhance their current level of performance. In the current scenario, there is a great need to include all the relevant sustainable manufacturing parameters with due weightage which may vary across different sectors of manufacturing. For future work, a comprehensive system is needed to apply this framework in manufacturing organizations, which may facilitate in promoting greater sustainability awareness, measurement and reporting.

### 5.1 Technology

The use of out-dated and outmoded technologies is a major challenge in the cluster. Availability of EE technologies, weak linkages with suppliers and low levels of knowledge on modern technologies are the main reasons for lack of technology up gradation in the cluster. Enabling policies for technology development and customization; demonstration of proven technologies and enhanced knowledge dissemination are necessary for facilitating technology up gradation in the cluster.

### 5.2 Energy

The share of energy cost in total production costs along with the price of energy is on the rise in Kolhapur. This is having a burden on maintaining competitiveness, especially



for the smaller units. In this context, EE is critical for the industry. There is immense scope for energy savings. Energy audits can recommend significant savings in not only melting and process technologies but also in auxiliaries, which consume a significant share of energy. However, the foundries in Kolhapur require step-by-step handholding for implementation of EE technologies. The process should involve identification of suitable technologies/practices along with suppliers/fabricators that can provide these technologies through energy audits. The foundries should then be sensitized on the investments, payback, and return along with concessional financing options available. The assistance should continue till implementation and even post implementation to ensure that the technologies implemented are being used along with best operating practices.

### 5.3 Marketing

The major market-based challenge facing the Kolhapur foundry industry is cyclical recessionary trends occurring in major end-use segments such as the automotive sector. Competition from China is also quite strong and requires industry to remain competitive. Therefore, it is important for Kolhapur foundries to minimize resources and costs. While energy is one important parameter, overall resource efficiency through adoption of lean manufacturing practices is critical.

### 5.4 Raw material and their quality

Availability of fresh sand is becoming a rising issue in the cluster. This is mainly because most units are not operating sand reclamation plants at their units. The cluster-level bodies have undertaken a PPP initiative which will establish two sand reclamation facilities in the cluster. This has been approved and is likely to considerably reduce demand for fresh sand in the cluster.

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# Sustainable Product Development: A Review

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**Abstract:** The aim of this paper is to give a review about sustainable product development (SPD). This paper's main contribution is the offering of a systematic review of the existing literature on sustainable product development, aimed at providing guidance on the topic, uncovering gaps and inconsistencies in the literature, and finding new paths for research. The review reveals the fact about level of implementation and awareness about SPD in India and its current state in Indian Small and Medium Enterprises (SMEs).

**Keywords:** Sustainable Product Development, Sustainable Manufacturing

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## 1. INTRODUCTION

The sustainability approach has gained tremendous attention since sustainable development was introduced by the Brundtland Commission in 1987. One important research aspect of sustainability is the move towards more sustainable products (Harald Gmlen, Stefan Seuring, 2014). The industrial world is increasingly aware of environmental impact of the products it makes, not only along manufacturing phase, but at all stages of product life cycle, from the initial stage of obtaining materials to the waste phase once that product life has finished. Sustainability has become a requirement for competitive companies, which can also enable them to achieve higher quality products, to improve the company image and to reduce the manufacturing costs (E. Lacasa et al., 2015).

Design development for technology plays a crucial role in modern economic growth. Design researchers and practitioners made advances in sustainable design by developing methodologies and tools to examine economic and environmental impact of the total life-cycle of product (S. Vinodh et al., 2013). Companies face challenges to develop sustainable products. This paper presents a review on sustainable product development to know the status of SPD in India. In product development stage, various design options can be identified using ECQFD, which helps to facilitate the design of environmentally sustainable products. TRIZ can be applied to manage trade-offs among conflicting parameters for design option and AHP can be used to evaluate and identify the most suitable design in an MCDM approach.

### 1.1 What is Sustainable Manufacturing?

After several decades of research in sustainable manufacturing (SM), there is still no common definition among scholars. One of the reason behind the large number of definitions is the many different interpretations of the 'sustainability' concept: e.g., seeing sustainability as an

environmental initiative; as a goal or a process; as an integration of different aspects; or as a compromise between pillars, etc (Anastasiia Moldvska, Torgeir Welo, 2017).

Sustain means to maintain or endure. Sustainability is the new paradigm in manufacturing which can be defined as the development that meets the need of present without compromising the ability of future generation to meet their own needs (Brundtland, 1987). United State's Environmental Protection Agency (EPA) has defined sustainable manufacturing as "the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. Sustainable manufacturing also enhances employee, community and product safety.

### 1.2 Why Sustainable Manufacturing is Required?

EPA has given numbers of reasons to state that why companies are pursuing sustainability or moving towards SM:

- Increase operational efficiency by reducing costs and waste
- Respond to or reach new customers and increase competitive advantage
- Protect and strengthen brand and reputation and build public trust
- Build long-term business viability and success
- Respond to regulatory constraints and opportunities

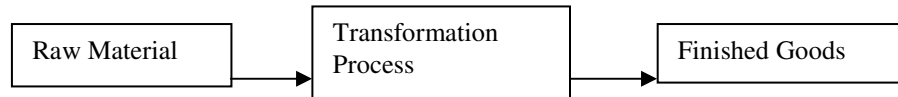
### 1.3 Difference between Conventional Manufacturing and Sustainable Manufacturing

The conventional manufacturing process can be defined as the transformation process of inputs like materials, machines, men, money, methods (5Ms) into desirable

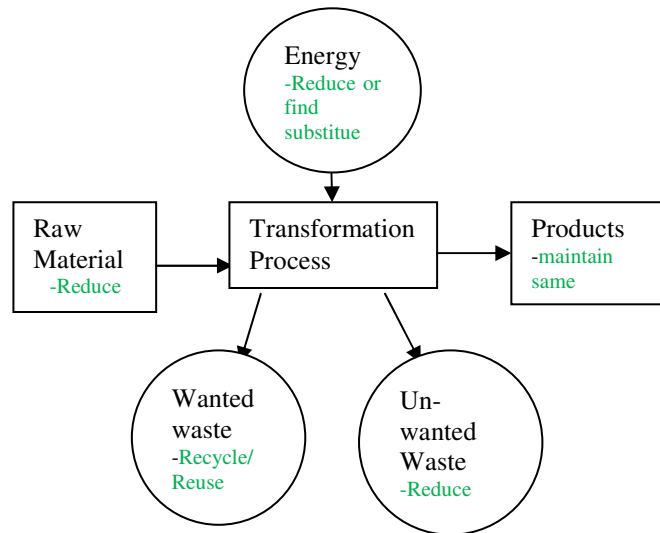
outputs (goods). Basically raw material is get converted into finished products. In this conventional manufacturing process, if we consider environment with 5Ms in input and include feedback (between output to transformation process or transformation process to input or output to input) in

order to improve efficiency, reduce waste & defects then it will become sustainable manufacturing.

Here the process chart of both conventional and sustainable manufacturing is shown.



**Fig.1 Conventional Manufacturing Process**



**Fig. 2. Sustainable Manufacturing Process**

Sustainable Manufacturing has environmentally driven objectives. It focuses on minimizing utilization of natural resources, minimizing energy consumption and minimizing the end waste. For converting conventional manufacturing to SM, we can reduce the uraw material and erngy usage or find its substitute to get same or increased quantity of end products. Each product creates waste during its manufacturing. Some wastes are wanted wastes (most probably solid wastes) which can be re-cycled and re-used and some of the gases are un-wanted which are pollutants or emission of gases like CO-2.

The rest of this paper is organized as follows. Section 2 briefly gives an idea about SPD. Section 3 presents a review of literature on SPD. Finally, conclusions are presented in Section 4.

## 2. SUSTAINABLE PRODUCT DEVELOPMENT

Sustainable development can be defined as balancing efforts to meet human needs without destroying or degrading environment. Simply product development can be defined as “the set of activities beginning with the

perception of a market opportunity and ending in production, sale and delivery of a product (Ulrich, Eppinger, 2003).” Generic product development consist many stages from idea generation to end use of product which includes initial feasibility, technical analysis, financial analysis, market analysis, market analysis, prototype development & validation, manufacturing and sales.

Sustainable product development is a method for product development that involves a framework for strategic sustainable development (FSSD), also known as the natural step framework. Sustainable product development is the framework which aims at the integration of economic, environmental and social consideration into product development (Tom Buchert et al., 2015). Product’s positive or negative impacts throughout its life cycle are determined by decisions during product development. Thus, it is important to integrate sustainability perspective in product development. Fig-3 shows the clear difference between traditional product development and sustainable product development.

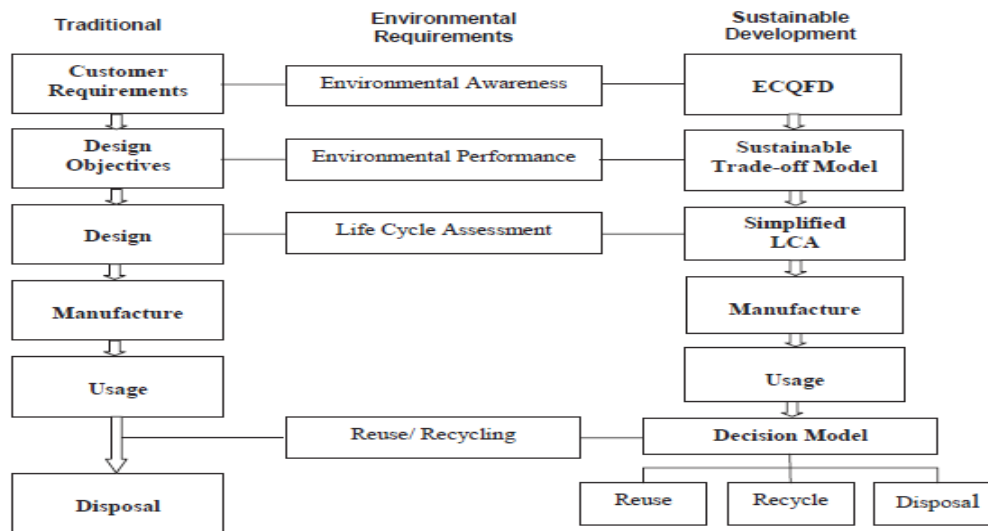


Fig. 3. Difference between traditional and sustainable development (H. kaebernick et al., 2003)

### 3. LITERATURE REVIEW

Nowadays, the most economic and effective way to carry out research is through the use of internet and databases. However, there is so much of information – effective and non-effective, reliable and non-reliable, authenticated and non-authenticated, and most importantly useful and non-useful. Therefore, Science Direct is used to start the search for quality research papers. To search articles various key words are used and juggled. The key word including ‘SPD’

used. However, the results turned up from many different areas and not from the Sustainable Product Development. The various researchers implemented SPD in case study organizations and also provided the SPD frameworks (conceptual, strategic, implementation, operational, etc.). ‘Sustainable product development’ used as a keyword, which did the trick and results were encouraging, so twenty seven articles were collected, which included case studies on SPD or framework for SPD and importance of SPD.

TABLE I: Contemporary literature review on SPD implementation

Sr. No.	Author and Year of Publication	Type of Industry	Country	Contribution
1	K. Madan Shankar et.al (2017)	Automotive	India	Sustainable manufacturing can be achieved by shifting the focus from 3R concepts to 6R concepts. Among the three dimensions of SPD, the "Environment" dimension gets more influential compare to other two dimensions. Industries should focus more on environmental-based practices.
2	Tom buchert et.al (2017)	-	Germany	Environmental issues should be integrated in early phase of design i.e at conceptual phase. Taxonomy criteria of the 29 selected SPD methods suggests that the majority of SPD mehods focus on assessment. However, many approaches also considers derivation of improvment measures and comparisons.
3	Ching-Hung Hsu et.al (2017)	-	China	It is difficult for SMEs to achieve sustainable enterprises because of shortage of resources. SMEs can effectively utilize their limited resources and prioritize their performance factor

Sr. No.	Author and Year of Publication	Type of Industry	Country	Contribution
				by using QFD as the basic structure and modified fuzzy extent analytic hierarchy process or any other MCDM tool to prioritize the performance factors.
4	Dominik Jasinski et.al (2016)	Automotive	UK	The automotive Sustainability assessment framework developed based on literature review and interview study. The framework shows that climate change, human health, ecosystem quality, resource depletion, dividends and taxes etc., affects the economic, environmental and social criteria of SPD.
5	Sverker Alange et.al (2016)	Furniture Manufacturer	Sweden	Sustainability initiatives can include introducing ideas or theories that focus on addressing stakeholder's needs. These stake holders are owners or financiers, customers, and employees.
6	Josef-Peter Schoggl et.al (2016)	Automotive	Austria	It is important to reduce cost and improve a product's sustainability performance in early phases of product development. The checklist for SPD can be developed to avoid lack of information and high degree of uncertainty.
7	E. Lacasa et.al (2015)	Solar tracker Assembly	Spain	Sustainability is the requirement for competitive companies because it enable them to achieve higher quality products, to improve company image and to reduce the manufacturing costs. Redesign strategy allows obtaining more sustainable products.
8	Nlizwa Rashid et.al (2015)	Automotive	Malaysia	Eco product innovation is crucial for firm's environmental performance, values creation and social development. Firm's resource and capabilities are the strategic weapons to success on reducing carbon footprint.
9	Tom buchert, Sabrina Neugebauer et.al (2015)	Bicycle frames Manufacturer	Germany	For developing sustainable products, design engineers need to foresee diverse interrelations between a product's characteristics and its economic, social and environmental impacts. MCDM problems comprise of an underlying space of feasible solutions and several objectives that can be evaluated with regard to the feasible solution. It helps to lead towards desired result.
10	Harald Gmelin and Stefan Seuring (2014)	-	Germany	The aspect of sustainability has often been neglected in new product development although new product development allows addressing sustainable characteristics upfront in the product life cycle. By going green in new product development, competitive advantages can be achieved.
11	Bin Lu et.al (2014)	Electronic and Electrical	China	Reuse can to help realize eco-efficient and sustainable waste management, with

Sr. No.	Author and Year of Publication	Type of Industry	Country	Contribution
		Equipment		environmentally friendly materials recovery. Reuse is one of the important strategy in 3R principles of waste management by which wanted waste can be reused again for the same purpose or a new application for which they were conceived.
12	Harald Gmelin and Stefan Seuring (2014)	Automotive	Germany	In triple bottom line approach of SPD, reduction of the consumption of natural resources below the natural reproduction leads to environmental aspects; skills, motivation, and loyalty of employees leads to social aspect; and guaranteed cash-flow at any time while producing return to share holders leads to social aspects. These all aspects should be incorporated in SPD.
13	Awanis Romli et.al (2014)	Medical Forceps	Malaysia	Quality function deployment can be used to support incremental, disruptive and radical product innovation. All product sustainability considerations can be conducted within a special eco-design house of quality.
14	Danni Chang et.al (2014)	-	Singapore	Sustainable development plays a crucial role in striking balance between the demands of social productivity and the reserves of natural resources. Life cycle assessment (LCA) is an important tool to assist in ensuring proper sustainability through assessing the environmental impacts of product designs.
15	Ida Gremyr et.al (2014)	-	Sweden	In SPD, there is the need of integrating sustainability in product development. This integration can be done by using eco-design tools like QFD which helps to integrate environmental aspects early in the product development.
16	Zhen-Yu Zhao et.al (2014)	Wind Power Industry	China	A questionnaire can be used to explore the most influential factors for SPD. This can be followed by a series of interviews with experts from industries. The respondents can express the level of agreement of each factor within certain scale.
17	S. Vinodh et.al (2013)	Automotive	India	TRIZ can be applied to propose innovative automated design alternatives. The best feasible alternative can be selected under multiple criteria using AHP.
18	Ilke Bereketli and Mujde Erol Genevois (2013)	Hand blender	Turkey	A multi aspect QFD for Environment (QFDE) is proposed to identify the improvement strategies by considering not only the end user's requirements but also the environmental stakeholder's ones. In order to define the priorities of all stakeholders' requirements, Fuzzy Analytic Hierarchy Process (FAHP) can be used.
19	Mario Fargnoli et.al (2013)	Gardening	Italy	It is important to operating at the design stage of

Sr. No.	Author and Year of Publication	Type of Industry	Country	Contribution
		equipment (Trimmer)		the product development process since it makes certainly easier for producers to reduce environmental impact, comply with safety requirements and, at the same time, meet customers satisfaction and economic constraints. Green QFD can be used at this stage to know product structure relationship and environmental impacts.
20	Sophie I. Hallstedt et.al (2013)	-	Sweden	If manufacturing enterprises truly want to support sustainable development, then it is important to have a common view on sustainability and to coordinate and integrate tools and methods for sustainable product development in the overall decision-making process.
21	Sami Kara et.al (2013)	-	Australia	The wave of change towards sustainability is clearly on enterprises, industries, communities and governments for thinking about solutions to increase the awareness in environmental sustainability and thus reduce carbon footprint. In some areas there is clear progress but for many, this process is just the beginning.
22	Pezhman Ghadimi et.al (2012)	Automotie	Malaysia	Lack of the weighting can have negative effects on precision. Weighted fuzzy assessment method for product sustainability assessment is developed. Fuzzy analytical hierarchy process was used to weight selected elements and sub elements.
23	M. Mani et.al (2012)	Automotie	USA	SPD is the framework that enables calculation of environmental impacts through key performance indicators and quantifiable metrics. QFD, AHP, Statistical and Quality tools can be used for design tradeoffs.
24	Effrosyni Petala et.al (2010)	FMCG	Netherland	Organizations need to communicate clearly and efficiently to project teams, as well as to senior management, what the company's goal is by including a section devoted to the impact of projects on environment and sustainability. The differences in goals that organizations want to achieve towards sustainable development place different challenges for the integration of sustainability considerations into the innovation process.
25	S. Vinodh and Gopinath Rathod (2010)	Rotary Switches	India	QFD emphasizes on quality in the design process to prevent the likelihood of defects at the early stages thereby reducing cost and improving productivity. Other benefits of QFD include reduced design changes, increased market share, and improved market quality.

Sr. No.	Author and Year of Publication	Type of Industry	Country	Contribution
26	H. Kaebernick et.al (2003)	-	Australia	Current practices of product development in manufacturing companies are still based on traditional cost/profit models, aiming at achieving high quality of a product at low cost and high profit. Environmental requirements are mainly considered as an unavoidable “must”, which generates additional design constraints and increases the costs.

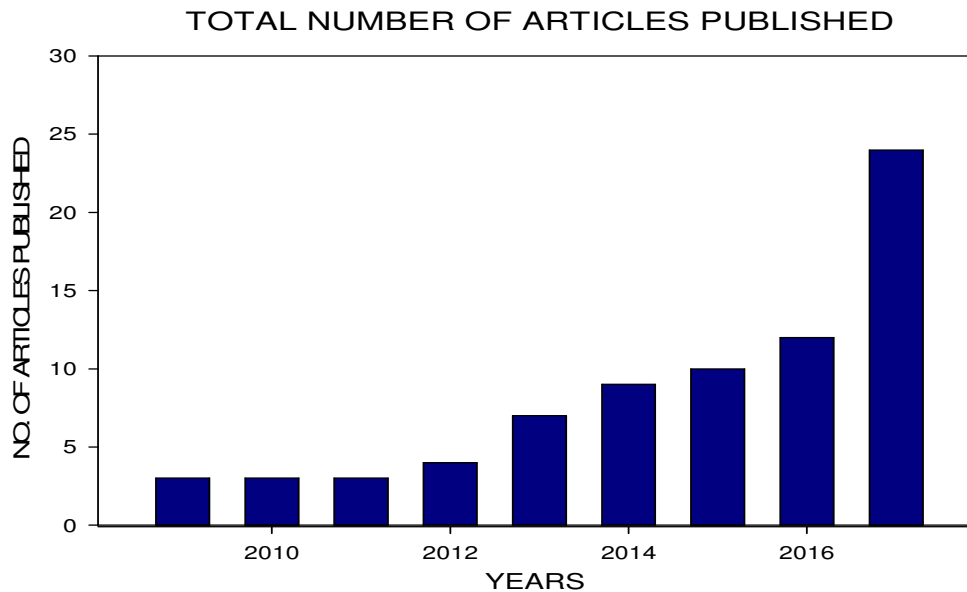
This table provides insights into currnt status of implementation of SPD and from the literatures it is observed that implementation of SPD increased in Germany, China and Sweden but the status in India is still in infant stage. The table provides an overview of implementation of SPD in various industries regardless of its type, size and location.

**TABLE II: Distribution of reviewed paper in various journals and conferences**

Journal	Number of References	%
Journal of Cleaner Production	30	40
Procedia CIRP	9	12
Renewable and Sustainable Energy Reviews	5	6.67
Int. J. Production Economics	3	4
Energy Policy	2	2.67
Journal of Engineering and Technology Management	2	2.67
Procedia Engineering	2	2.67
Procedia Manufacturing	2	2.67
Resources, Conservation and Recycling	2	2.67
Resources Policy	2	2.67
Applied Mathematical Modelling	1	1.33
CIRP Journal of Manufacturing Science and Technology	1	1.33
Computers & Industrial Engineering	1	1.33
Current Opinions in Green and Sustainable Chemistry	1	1.33
Energy	1	1.33
European Journal of Operational Research	1	1.33
Experts Systems with Applications	1	1.33
Industrial Crops and Products	1	1.33
Industrial Marketing Management	1	1.33
International Journal of Production Research	1	1.33
Int J Life Cycle Assess	1	1.33
Journal of Environmental Management	1	1.33
Journal of Manufacturing Technology Management	1	1.33
Procedia Social and Behavioral Sciences	1	1.33
Robotics and Computer Integrated Manufacturing	1	1.33
Sustainable Energy Technologies and Assesments	1	1.33
Total Number of Papers	75	100



Total 75 papers reviewed from 26 international journals over period of 2009 to 2017



**Graph. 1 Year Wise Distribution of Articles Published**

The graph.1 depicts trend of SPD publication, which shows increasing trend of publication from 2009 with 3 publications only to 2017 with 24 publications. It is observed from the increasing trend that SPD awareness is gradually increasing.

**TABLE III: Country wise paper published for developed and developing countries**

Sr. No	Country	Developed or Developing Country	Number of Paper Available	%
1	Sweden	Developed	12	16
2	China	Developing	10	13.33
3	Germany	Developed	8	10.67
4	Australia	Developed	4	5.33
5	Malaysia	Developing	4	5.33
6	UK	Developed	4	5.33
7	Brazil	Developing	3	4
8	India	Developing	3	4
9	Norway	Developed	3	4
10	USA	Developed	3	4
11	Finland	Developed	2	2.67
12	Spain	Developed	2	2.67
13	Turkey	Developed	2	2.67
14	Austria	Developed	1	1.33
15	Belgium	Developed	1	1.33
16	Canada	Developed	1	1.33
17	Denmark	Developed	1	1.33
18	Detroit	Developing	1	1.33
19	Hongkong	Developed	1	1.33

Sr. No	Country	Developed or Developing Country	Number of Paper Available	%
20	Indonesia	Developing	1	1.33
21	Italy	Developed	1	1.33
22	Japan	Developed	1	1.33
23	Mexico	Developing	1	1.33
24	Netherlands	Developing	1	1.33
25	Poland	Developed	1	1.33
26	Serbia	Developing	1	1.33
27	Singapore	Developing	1	1.33
28	Switzerland	Developing	1	1.33
Total Papers			75	100

The purpose of above table is to show the publications in developed and developing economies. The table depicts the awareness of SPD in Germany, China and Sweden is developed. The table also shows SPD making inroads into Australia and Malaysia. However, SPD in India is still under development and it is yet to mark its impact.

#### 4. CONCLUSION

From the literature review, it can be said that there is very less awareness about SPD in India. Considerable research needs to be done in SPD as it is not widely adopted. The literature review shows the implementation of SPD with positive result in other countries. Lot of work is need to be done to implement it in Indian SMEs. SPD is the strong methodology to reduce environmental impact and to lead society towards sustainability. SPD is the new tool or approach that will lead to improve economic and environmental performance by reducing material usage and energy consumption. SPD also includes Social impact by considering employees, stake-holders and customer relationships.

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# Identification and Evaluation of Factors for Green Manufacturing at Indian Cement Industry

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**Abstract:** Green Manufacturing (GM) process addresses a number of manufacturing issues, including recycling, conservation, waste management, environmental protection, regulatory compliance, pollution control, and a variety of other related issues. By understanding, each research study approach and upon conducting proportional analyses, in order to develop insights into the evolution of green technology projects. The findings indicate that GM is positively and significantly related to Indian cement industry and it partially mediates the relationship between three important performance measures, product quality, product manufacturing, and process manufacturing. The results for size and capital-intensity validate the importance of GM practices for smaller firms and environments that are more frequent intensive. Investing to achieve a broader, deeper, and more mature GM implementation should also result in higher benefits from GM implementation. Our research attempt integrates CSF's in the development of a GM framework and is the first in the cement industry. The main highlights of this research is a proposed framework for green manufacturing process as well as a discussion of potential ways that covers the entire product life cycle from conceptual design to disposal in a benign, harmless manner causing no or minimal adverse impact on environment by optimum use of resources and reduction of waste and pollution.

**Keywords:** Green Manufacturing Framework; Indian Cement Industry; Critical Success Factors; Performance management.

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## 1. INTRODUCTION

The Indian cement industry has evolved significantly in the last two decades, going through all the phases of typical cyclical growth process. After a period of over-supply and a phase of massive capacity additions, the industry is currently in a consolidation phase (Rehan et al. 2005). With sound economic growth and infrastructure development, the demand for cement is on an upward trend. This paper presents the details of a case study (Soguta et al. 2009). It highlights the road map of the company for achieving performance improvement through GM implementation and its impact on organizational performance (Alia et al. 2011).

### 1.1 DEFINITION OF GREEN MANUFACTURING

Green Manufacturing is a method for manufacturing that minimizes waste and pollution for all industries. It slows the depletion of natural resources as well as lowering the extensive amounts of trash that enter landfills (Chung et al. 2011). Its emphasis is on reducing parts, rationalizing materials, and reusing components, to help making products more efficient to build. In industry's, energy demand is one-third of the total energy consumption in the world. Limited natural resources may be used to generate this energy (Srivastava et al. 2012).

### 1.2 ROLE OF GREEN MANUFACTURING CEMENT

The Beginning of Indian Cement Industry The attempt to produce cement in India dates back to 1889 when a Calcutta

firm attempted to produce cement from Argillaceous (Desai et al. 2013). Green, or sustainable, manufacturing is defined as a method to “develop technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste”. The term “green”, often used interchangeably with “environmentally-safe”, comes from ideology that was originally developed by the Green Party, a political party in Australia in the early 1970's, whose political agenda quickly spread around the world (SÖGÜT et al. 2012). Life cycle assessment (LCA) is rapidly emerging as a useful environmental management tool worldwide for many process industries including cement manufacturing (Desai et al. 2012).

### 1.3 ORGANISATION OF THE PAPER

This paper is organised as follows: Section 2 covers literature review and is divided into three subsections. Section 3 describes about GM structure and background of the problem considering existing distribution scenario. Section 4 describes the research process and framework. Section 5 discusses the result analysis with different six subsections. Section 6 includes discussion and Result of the model. Section 7 concludes the study with a comparative analysis of the pre- and post-implementation scenario and summarises the findings. Section 8 covers the limitations and future scope of the study.

## 2. BRIEF LITERATURE REVIEW

The purpose of this brief review is to tabulate the critical success factors and performance measures by covering select and recent studies. Authors are providing useful tables that is why description has been kept as minimum as possible.

The review is divided into three parts. First part guides about what CSF means and major studies in the areas of green manufacturing to boost CSF for different industry. Second part discusses and guides about what PMs means and the major studies in the areas of green manufacturing to boost PMs for different industry. Third part helps in highlighting the research gaps and weaknesses.

Luthra et al. 2015 has proposed a method for common management options for copper slag, such as recycling, recovering of metal, production of value added products such as abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements.

Chuang et al. 2014 have proposed a three-layer assessment model to evaluate the performance of a green-manufacturing system (GMS) and identify the key success factors of its real-world implementation. The top layer of the model includes three dimensions – green design, green-manufacturing process and green packaging. The practicality of the proposed model was demonstrated by evaluating three companies that produce similar products and share similar business models.

Rahman et al. 2013 have proposed process for energy consuming and heavy polluting. In this paper he has summarized and reviewed on the usage of different types of alternative fuel and their impacts on the plant performance.

Seth et al. 2009 have presented in depth review of these cases to facilitate the transition from laboratory to industrial scale. It was demonstrated that tangible results can be achieved with present-day technology and that one of the major barriers is economic. However, authors GM model has proved this design approach for the environment and environmental management process to be positively correlated with performance.

Darshak et al. 2012 have presented earliest surveys on GSCM practices in Indian manufacturing firms. The items for the survey were developed based on the extant literature and feedback from corporates. Authors found that the state of adoption of GSCM practices by Indian firms was still in its infancy. According to Mohanty et al. 2014 have proposed a technique for green supply chain practices only to the extent of their participation as suppliers, distributors and in other capacities as business partners.

Doğan et al. 2014 have Data for this study was collected from a highly educated sample of 200 respondents using a

structured questionnaire. The questionnaire contains questions to measure general consumers' environmental concern, awareness of eco-friendly products, trust in performance of eco-friendly products and green buying behaviour. Descriptive statistics, factor analysis and correlation techniques were used to analyze the findings of this study.

### 2.1 RESEARCH GAP:

From the literature review, following gaps and weaknesses are identified. These gaps clearly indicate that researchers are not considering management aspects, are focussing on emission control technologies, and are advocating manufacturing based frameworks whereas, cement industry is a process industry, behaves in a different manner. Other important gap area is in terms of lack of empirical studies. It is observed that majority of the studies are discussing modelling aspects and studies covering empirical relationships are practically missing. Authors are explaining these gap areas by citing appropriate studies.

- Increased industrialization and urbanization have led to significant growth in waste generation and environmental pollution. However, authors GM model has proposed to be a GM concept to grasp and definition relative to the construct is still considered not adequately answered (Fonga et al. 2009).
- There is a lack of empirical studies in process industry in a developing country context such as Indian cement industry. Modelling sustainable, environmentally conscious manufacturing processes systems and analytical tools for assessing the impact of processes. Authors are discussing the Modelling sustainable, environmentally conscious manufacturing processes, which strongly suffices this proposed model (Gustavsson et al. 2006).
- Converting pollutants and wastes such as ash into by products and promote their utilization and recycling along with the use of the product is the need for modifying an industry like cement industry. Authors (Luthra et al. 2011) are proposing a green manufacturing model, which Authors believe is expected to be a very useful framework for Indian cement industry. However, authors GM model has proved this design approach for the environment and environmental management process to be positively correlated with performance (Mandal et al. 2011).

They lack awareness on green environmental initiatives and their associated funding process. These GM process are being considered as the backbone of the Indian manufacturing process but they are not seen to be showing much interest in greening their manufacturing operations. Therefore, the new purpose model of this paper is to investigate the green manufacturing conforming to the different practices/activities of the GM.

## 2.2 OBJECTIVE

To study the progress of Indian cements industry since 1991, in terms of its growth in installed capacity, production, exports, and value additions. The basic objective of this study was to analyze the CSF and PM via factor analysis implementation in Indian cement industries. The CSF and PM used in this study were derived from existing literature review of green manufacturing, factor analysis and regression analysis (Wang et al. 2011). In this paper, we are presenting the list of 6 major CSF and PM factor with their sub elements as generated from the literature review. In this work, six CSF to implement GM practices and six performance measures are identified through extensive literature review. The application of the methods and techniques used in this work is explained in the following subsections.

## 3. RESEARCH METHODOLOGY

To establish an assessment model and extract CSF and PM associated with implementing a GM, this work integrates a three stage procedure and a two-stage questionnaire to collect expert opinions from cement industry from all over India. These factors cover the three key aspects of every CRM strategy: human factors, processes and technology. (Desai, 2013) presented the CSF and PM model for successful green manufacturing implementation within Indian cement industry. In this model survey to determine the world-class status of Indian manufacturing companies and suggested that companies must align their green

initiatives towards facilitating agile manufacturing rather than introducing green to merely automate their conventional operations. Since the number of such factors is large, each capable of influencing the most of others to varying degree, it is very difficult, if not impossible, to consider them all. In this paper, we are proposing, the first questionnaire modifies the initial model in stage two and the second questionnaire weights the dimensions, strategic subjects and assessment factors in stage three.

The authors spent significant time at all over from India, the process industry, the major distribution centres, major wholesalers and covered the last link of the chain that is up to retailers. Interview reports along with additional notes and observations were shared with the participants to enable them to check for advantages and disadvantage and to evaluate the validity of researchers' interpretation and description. This really helped authors in developing, testing and even refining an operational understanding of the concepts and measures, as was necessary in this study.

## 4. RESEARCH FRAMEWORK IDENTIFIED FOR INVESTIGATION

The research methodology aids the researchers in the allocation of limited resources by posing crucial choices. Its essentials are depicted in Figure 1. This research was conducted between July 2014 to January 2015 across India zone. For data collection, questionnaire was administered in two steps:

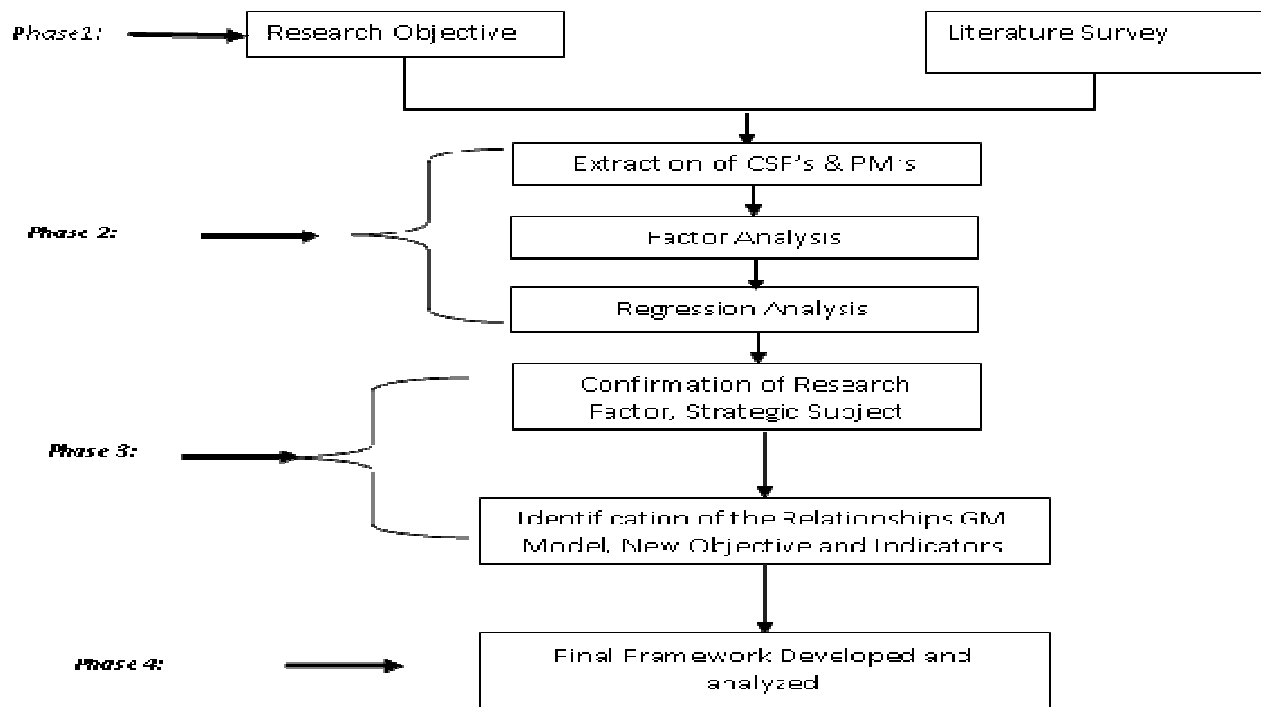


Fig. 1.

#### 4.1 DATA SOURCE

The data has been collected from both primary and secondary sources. The primary source consists of a questionnaire survey. 450 structured questionnaires had distributed to the respondents throughout the world for the purpose of gathering needed data. All the questions have designed in such a way that the responses generated on the crucial issues which are directly and indirectly focused on the research goals. This data helps in making projections in this research investigation in cement industry (Nunes et al. 2010). The secondary source is also included scanning and searching of related past works in print form and electronic form on websites.

#### 4.2 SAMPLE SIZE, IMPORTANT STEPS:

In the present research, a sample size of 500 (collected from all over India) was chosen for the final survey. However data collection through questionnaire method has several advantages but it also have so many disadvantages like Low rate of return of the duly filled in questionnaires. The questionnaire was mailed along with prepaid envelop in order to facilitate quick reply. They were entrusted with the responsibility to answer the queries of the respondents and also to do follow up. The hectic efforts and the support of the friends and institutes generated a good response representing 48% response rate which was quite encouraging. Table 3 gives details about the profile of the respondents.

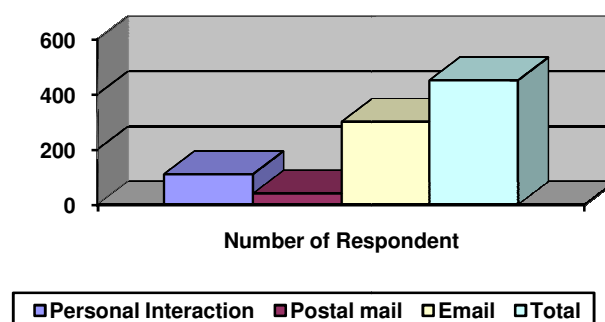
It was decided to use Delphi method to identify operating measures, as necessary expertise was available. Delphi method is a very flexible approach, and permits to reach a consensus, through the collection of experts' opinions on a given issue during successive stages of discussions, questionnaire and feedback. As identified by (Chung et al. 2008), 'Delphi method is well suited as a research instrument when there is incomplete knowledge about a phenomenon or problem'. Interview reports along with additional notes and observations were shared with the participants to enable them to check for advantages and disadvantage and to evaluate the validity of researchers' interpretation and description (Deif et al. 2011; Vachon et al. 2006). This really helped authors in developing, testing and even refining an operational understanding of the concepts and measures, as was necessary in this study.

#### 4.3 DATA ANALYSIS:

The collected data was analysed (using SPSS IBM software) by following percent analysis procedure as paper requirement. Percent Analysis is a general name denoting a class of procedure primarily used for data reduction and summarization (Chung Shang et al. 2010; Zhu et al. 2009). In research survey, there may be a large number of variables, most of them are correlated and which must be reduced to a manageable level and interpretable.

**TABLE 1: Instrument receipt mode details**

Sl. No.	Data Collection mode	Number of Respondent
1.	Personal Interaction	110
2.	Postal mail	40
3.	Email	300
4.	Total	450



**Fig. 1. Instrument receipt mode details**

In Table 1: This is sufficiently respondent result in receiving 450 valid instruments out of 500 with the response rate 95%. In this table, the response rate is quite encouraging.

#### 4.4 RELIABILITY CHECKS AND OTHER SUPPORTIVE DETAILS:

The purpose of factor analysis is to find a way of summarizing the information contained in a large number of original variables into a smaller set of new composite dimensions with a minimum loss of information. The Bartlett's test of sphericity and the KMO measure of sampling adequacy were employed to test the appropriateness of the data for reliability analysis. Eigen values of discontinuity in excess of 1.0 and reliability loading exceeding 0.5 were used as the principle in choosing reliability analysis. For reliability estimation, Cronbach alpha value exceeding 0.7 is considered to have high internal consistency of the scale.

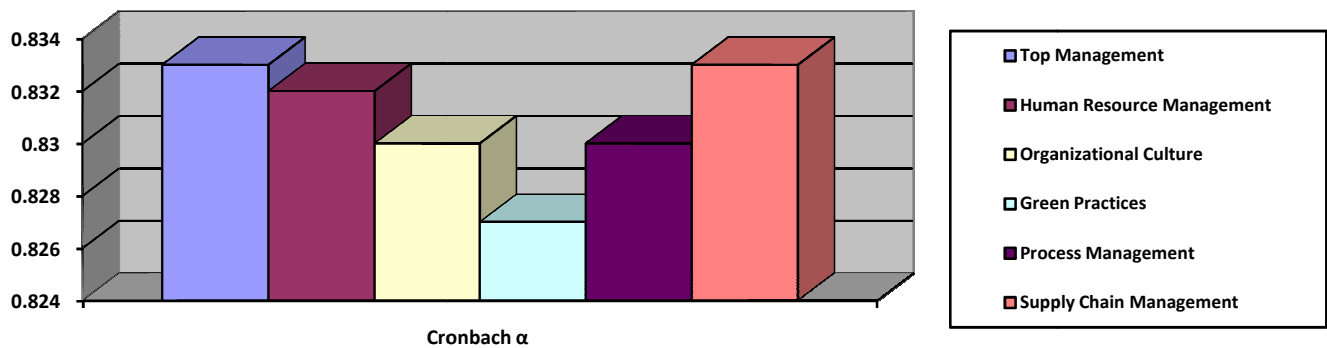
Authors analysed respondent's responses, for internal consistency. The reliability analysis of a questionnaire determines its ability to yield consistent results. Reliability was operational as internal consistency, which is the degree of inter correlation among the item which comprise a scale. The Cronbach's alpha of questionnaire with 81 attributes/items was found to be 0.992, implies that the questionnaire is reliable. Also the reliability of individual scales was tested found to be varied 0.892 to 0.895. Since the reliability coefficients of all the individual scales are above 0.7 considered adequate, all the developed scales indicated acceptable reliability. The first step, prior to running the reliability analysis, the Kaiser-Meyer-Olkin

(KMO) measure of sampling adequacy and the Bartlett's test of sphericity were conducted. (Nunnally, 1978). The KMO value was found to be 0.787, which is greater than 0.5, which indicated sample adequacy for reliability, and supporting the appropriateness of using reliability to

explore the underlying attributes. The Bartlett's test of sphericity was highly significant ( $p < 0.000$ ) significance value of Bartlett's test is 0.000, rejecting the null hypothesis that the 36 important attributes are uncorrelated in the population.

**TABLE 2: Factors based verification on KMO-Cronbach  $\alpha$  results for CSF**

Factor	Factors based on survey results	Cronbach $\alpha$	KMO	The average variance explained by these factors (cumulative)
Factor-1	Top Management	.833	.573	4.320
Factor-2	Human Resource Management	.832	.643	4.103
Factor-3	Organizational Culture	.830	.678	4.574
Factor-4	Green Practices	.827	.707	4.605
Factor-5	Process Management	.830	.667	4.107
Factor-6	Supply Chain Management	.833	.696	3.874



**Fig. 2. Factors based verification on KMO-Cronbach  $\alpha$**

**TABLE 3: Factors based verification on KMO-Cronbach  $\alpha$  results for PM**

Factor	Factors based on survey result	Cronbach $\alpha$	KMO	Average variance explained by these factors (cumulative)
Factor-1	Quality Performance	.976	.864	4.069
Factor-2	Resource Utilization Performance	.972	.918	3.809
Factor-3	Financial Performance	.982	.769	3.961
Factor-4	Green Performance	.973	.901	4.283
Factor-5	Employee Satisfaction	.967	.978	4.379
Factor-6	Customer Satisfaction	.967	.978	4.315



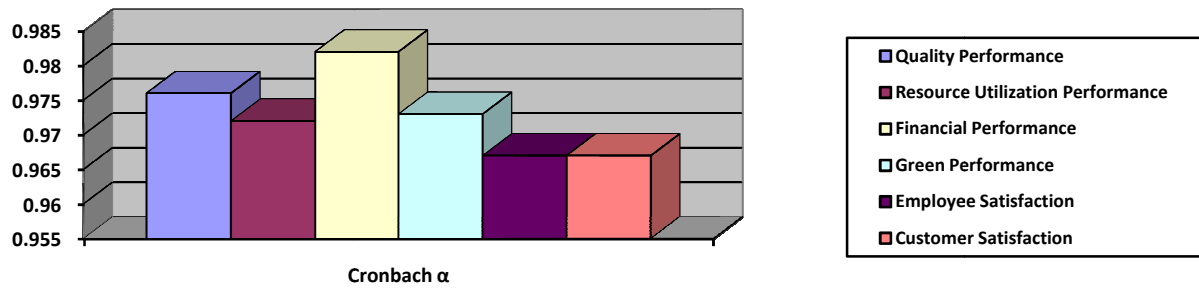
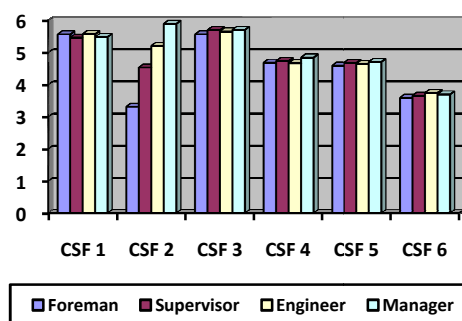
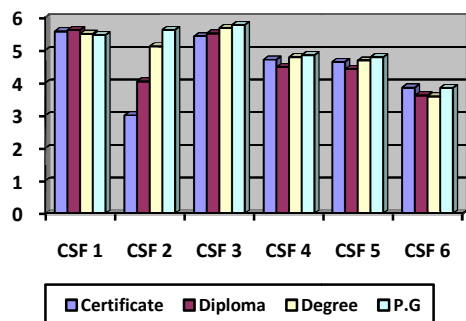


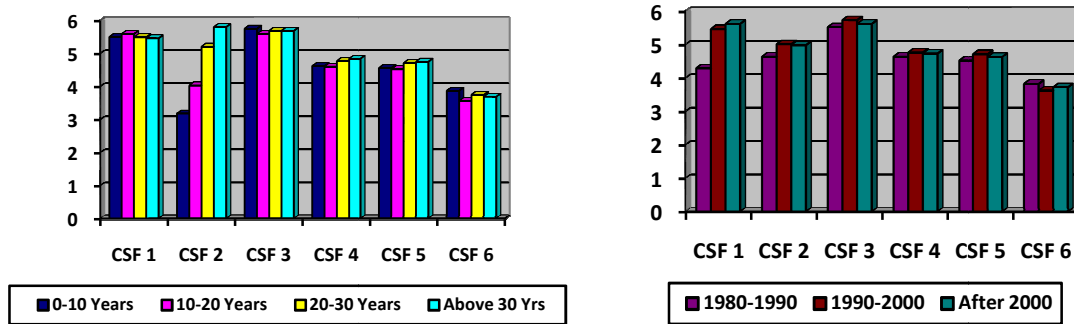
Fig. 1. Factors based verification on KMO-Cronbach  $\alpha$

#### 4.5 MEAN AND ANOVA ANALYSIS:

TABLE 4: Mean and ANOVA for Qualification of Respondent and Critical Success Factors

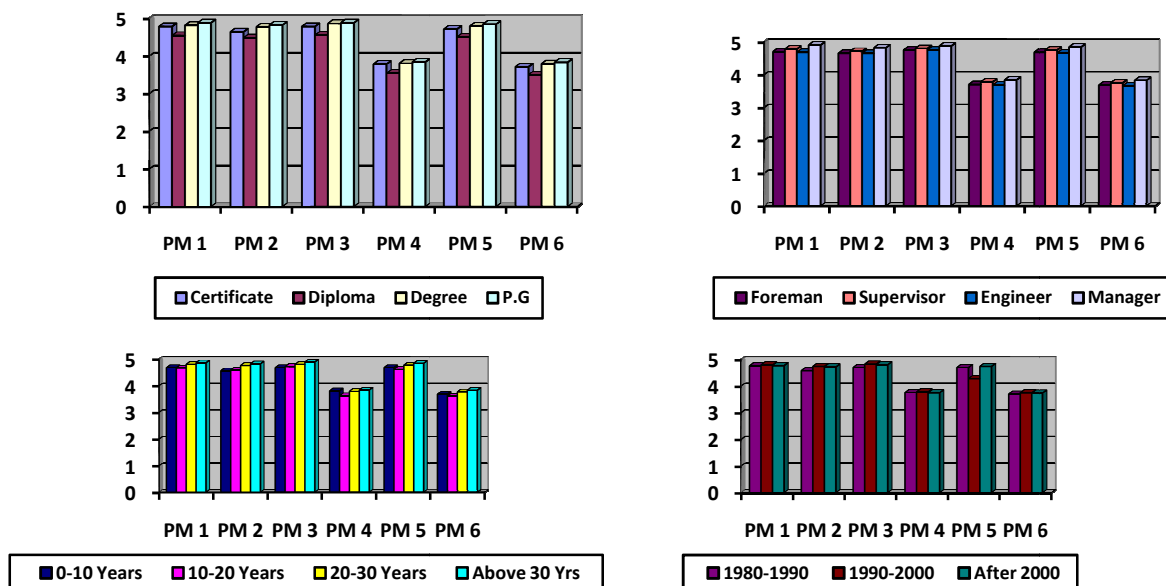
Category	CSF 1	CSF 2	CSF 3	CSF 4	CSF 5	CSF 6
Certificate	5.57	3.00	5.42	4.71	4.64	3.85
Diploma	5.61	4.04	5.51	4.48	4.42	3.61
Degree	5.50	5.11	5.68	4.78	4.68	3.58
P.G	5.46	5.62	5.77	4.84	4.78	3.84
Foreman	5.56	3.31	5.56	4.68	4.59	3.59
Supervisor	5.46	4.53	5.69	4.73	4.67	3.65
Engineer	5.57	5.20	5.65	4.66	4.64	3.74
Manager	5.48	5.89	5.70	4.84	4.70	3.69
0-10 Years	5.50	3.18	5.75	4.62	4.56	3.87
10-20 Years	5.59	4.03	5.59	4.60	4.52	3.56
20-30 Years	5.49	5.21	5.69	4.77	4.71	3.75
Above 30 Yrs	5.46	5.80	5.69	4.84	4.75	3.69
1980-1990	4.29	4.64	5.52	4.64	4.52	3.82
1990-2000	5.46	5.01	5.73	4.76	4.71	3.62
After 2000	5.62	4.98	5.62	4.73	4.63	3.72





**TABLE 5: Mean and ANOVA for Qualification of Respondent and Performance Measures**

Category	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6
Certificate	4.78	4.64	4.78	3.78	4.71	3.71
Diploma	4.54	4.48	4.55	3.54	4.50	3.50
Degree	4.81	4.77	4.86	3.80	4.79	3.79
P.G	4.88	4.82	4.88	3.84	4.84	3.83
Foreman	4.70	4.65	4.75	3.70	4.68	3.68
Supervisor	4.78	4.71	4.80	3.78	4.75	3.75
Engineer	4.68	4.65	4.75	3.68	4.66	3.66
Manager	4.90	4.82	4.87	3.84	4.84	3.83
0-10 Years	4.68	4.56	4.68	3.81	4.68	3.68
10-20 Years	4.67	4.59	4.72	3.62	4.61	3.61
20-30 Years	4.80	4.76	4.80	3.79	4.77	3.77
Above 30 Yrs	4.86	4.82	4.89	3.84	4.84	3.83
1980-1990	4.76	4.58	4.70	3.76	4.70	3.70
1990-2000	4.79	4.74	4.82	3.78	4.28	3.75
After 2000	4.77	4.72	4.80	3.75	4.74	3.74



The test results of KMO show that the compared value is 0.97, significantly exceeding the suggested minimum standard. Bartlett's Test of Sphericity is also significant. Based on the above tests, it is evident that all performance measures are suitable for applying factor analysis. In our case, all CSF and PM have factor loading greater than 0.7. All the Cronbach's alpha values in our study are greater than 0.7, revealing the high internal consistency. Reviewed the literature on sustainable supply chain management and defined social performances as an improving and maintaining people's quality of life without damaging the environment and over exploiting the resources contained in it. Operational Performances include decrease of fine for environmental accidents, improvement in environmental quality of products/processes, improved brand image, increase in customer awareness level and increased customer's satisfaction & loyalty. Numerous researchers identified environment performances in greening the supply chain. Environmental Performances include reduction in air emissions, liquid & solid wastes, decrease in use of harmful/hazardous materials/components and extent of recycling & reuse activities. Environmental performance has been well-established in automobile manufacturing industry in developed countries. Now, it is also becoming important for developing countries like India.

## 5. RESULT AND DISCUSSION

The results of this study suggest that in general, the elements of strong relationship are significantly related to the measures of organizational performance. This paper will make basic change in the way green product, gas estimation, green supply chain management, wasted materials and recycle their wasted materials by integrating environmental manufacturing model. We are dealing with deployment of different GM tools insight process. An integrated assessment of green cement production processes under green, but also under technical and economic aspects requires specific methods with minimum energy efficiency during the product's manufacturing. Their environmental results are made, the origin of the ideas for development and normal actions of environmental performance measures are anal size, as well as the test of a critical success factors model that helps the environmental decision-making process.

## 6. CONCLUSIONS

In this paper, an attempt has been made to review the literature on GM in cement industry. The authors had presented a literature classification and categorized content related to cement industry. This paper will assist researchers and cement industrialist to understand and integrate GM in cement industry. However, few of them focus on studying the life cycle and green product design by the help of GM process. Available resources should be used effectively and efficiently to achieve Green productivity

with Green industry. In this paper, a challenge has been made to explore green process responsibility for initiating quality management in cement industry and planning for performance management in cement education by evaluating percent analysis. Here I have intended to propose a proper changed in perspective of GM. The information obtained in the current study will be invaluable not only for finding all gases emissions, but also for assessing the most practicable ways of making improvements to dust air quality, waste utilization and environment protection.

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# Sustainable Manufacturing: A Review and Application in Indian Manufacturing Industries

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**Abstract:** In today's global scenario, the manufacturing industry has play a vital role in the global economy by supplying goods and services which shows greater influence towards building the economy of many nations including developing countries. Manufacturing firms are consuming non-renewable resources in un-manageable manner and discharge high amount of pollutants and un-controllable waste in the environment which leads to environmental degradation and health issues to the society. This environment and social problems are becoming challenges for manufacturing sector. Manufacturing sector is the backbone of India, as it not only provides enormous employment in all categories of work force but also helps in raising exports and foreign direct investment (FDI). But this sector is facing many new challenges in recent time. Present study is an attempt to explore the various studies carried out in Sustainable manufacturing at international & national level, role of manufacturing in Sustainable Manufacturing and the challenges faced while implementing Sustainable Manufacturing.

**Keywords:** Sustainable Manufacturing, Sustainability, Manufacturing Industries, India

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## 1. INTRODUCTION

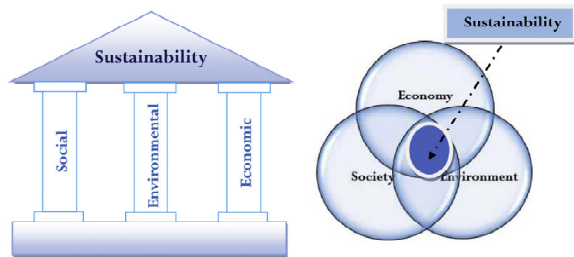
The definition of sustainability which most of the authors have referred is: "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987). From the above definition all the concepts related to the environment protection, wastes reduction, recycling, natural resource conservation can be categorized under sustainability. Different domains have different interpretation regarding the Sustainability as a concept as well as its implementation. For example, if we are considering business field then it is defined as "adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future" (Kulatunga, Jayatilaka and Jayawickrama, 2013). Sustainable manufacturing can be defined as "The production of manufactured products that use processes which minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound" (Garreti and Taisch, 2012). In today's scenario of environmental issues, if proper strategies can be framed then Sustainability can possibly be considered as the linkage to integrate the requirements of society, environment and economy. Though from definition and concept wise it is easy to understand what actually sustainability is but rather difficult when it comes to the implementation stage as many challenges are there (Deshmukh, 2012). Sustainable manufacturing can be considered as the most important aspect in manufacturing industries for transforming raw inputs into finished outputs through accomplishment of reduced energy consumption,

negative environmental effect, greenhouse gases and generation of waste.

Increasing world population is imposing large demand on natural resources with the escalating environment impact of the current manufacturing processes are continuously pointing towards the global revision to Sustainable Manufacturing. Economy, environment and social are the three main features of sustainability which were considered in the report of United Nations General Assembly, 1987 as shown in Figure 1. To maintain the stability of the manufacturing process it is very much essential that three pillars should be integrated and should be perform as an integrated system rather than individual. Basically the aim of this integrated system is to achieve overall environmental sustainability with consideration of the economic as well as social aspects by minimizing the loss of environmental resources, reducing the emission of harmful pollutants & gases, recycling and remanufacturing.

Major of manufacturing industries consume large amount of conventional resources for producing products which resulted into various types of wastes and pollution. However with increasing SM awareness, industries have started finding out various ways to reduce these harmful wastes and pollution for achieving sustainability (United Nations General Assembly, 1987). It clearly indicates that manufacturing industries are required to adopt new paradigm which can produce products without compromising environmental standards. Sustainment of environment standards also fulfils the requirements of pollution free healthy life to the customers, employers, and communities of society. In recent times many articles have been published stating the need of tackling triple pillars as

shown in Figure 1. It is to be noted that any environmentally proactive activities such as sustainable manufacturing will lead to competitive edge for the industry in the marketplace and will lead to achieve sustainable business practices. The relationship between manufacturing outcomes and sustainable manufacturing showed that pollution prevention practices are associated with a decrease in manufacturing cost.



**Fig. 1 Pillars of Sustainability (United Nations General Assembly, 1987)**

## 2. ROLE OF MANUFACTURING IN SUSTAINABLE MANUFACTURING

Manufacturing firms are consuming non-renewable resources in un-manageable manner and discharge high amount of pollutants and un-controllable waste in the environment which leads to environmental degradation and health issues to the society. This environment and social problems are becoming challenges for manufacturing sector. In today's scenario, population of planet is growing rapidly and also demanding for the industrial goods when the available resources are scarce in nature. In this scenario, developed countries are trying hard for attaining the better standard of living. In the process of attaining this standard, manufacturing industries of the developing countries are required to be sustainable in their processes with strategic alignment of the planning towards environment consciousness. This can be achieved by adopting more sustainable practices in manufacturing sector which considers the triple bottom line with the three dimensions (Economic, environmental and social) of sustainability which is in urgent need.

The limited strength of the environment or eco-system to conserve the emissions produced by current carbon-based economies imposes a negative impact not only to natural equilibrium, but also to our own daily conditions of living (Edenhofer et al., 2014). According to (Meadows et al., 2004) the most effective unsolved issue in current scenario is that pace of the consumption of the global conventional resources is more than they can be refurbished, while discharge of wastes and pollutants quicker than the nature can engross them.

Although there is so many discussion regarding prevention of negative impact of the current products, processes and services on the eco-system with consideration of the

economic and social aspects, but the need is now to initiate some impactful implementation and actions to actually practicing the concept. Rosen and Kishawy, (2012) suggested that despite international efforts to sustain eco-system, the global energy system is carbonizing due to a global renaissance of coal. As per (European Commission, 2006) the potential savings are estimated to be 25 %, representing annual losses of about 100 billion euros especially for the industries if they are focussing on the sustainability by minimizing the loss of environmental resources, reducing the emission of harmful pollutants and other harmful gases, and recycling and remanufacturing. It was also observed that there is expectation of the further increase in the energy consumption in the world scenario in effort of to compensate the need of increasing population and need of growth (Gutowski et al., 2011).

For manufacturing sector to maintain the sustainability it is required to monitor the impact of each stage of the product with focus on analysing the negative impact it poses on the environment because it is possible that the product may not have negative impact in production stage but at different stage of life cycle it may be harmful to the environment (Duflo et al., 2012). However report also claimed that improvement has been realised over last decades in manufacturing sector regarding working conditions (World Health Organisation, 2013). The manufacturing sector is considered to be the most robust sector for strengthening the economy of any country. Manufacturing sector produces 31 % of the world Gross Domestic Product (GDP) and that can be investigated if it is also contributing towards actual wealth (US central intelligence agency, 2016). According to (Vinodh and Joy, 2012), to achieve economic stable development especially for the developing countries, manufacturing sectors growth plays a major role and for accomplishing that manufacturing sector needs to sustain their processes so that their negative environment effects can be reduced. Such a way manufacturing sector can be act as an enabler for sustaining and improving the economy of the country.

According to (World Development Indicators, 2013) the percentage contribution of manufacturing sector in Indian GDP is around 13-16% which reveals the fact that manufacturing sector contributes a vital role for strengthening the economy of developing country like India. However it further also revealed that the percentage contribution has shown decline trend from January, 2007. India is considered to be the most influencing economy around the world and it may also continue its efforts toward sustaining their growth for the next two decades. It is to be considered that for sustaining this growth, India has to overcome some of the barriers such as conserve natural resources while producing quality products at reduced cost, match with the increased demand of the survival commodities due to increased population, reducing negative environmental effects of the traditional manufacturing

processes, developing advanced production technologies to reduce harmful side-effects of traditional processes etc. Joung et al., (2013) observed that increase in advancement of production technologies will result into various wastes and pollutants whose disposal will lead to harmful negative effects on the environment. This can restrict India to sustain their growth in the future. Above discussion clearly highlighting that India needs to consider the negative environment effects together with economy development in future and for attaining that sustainable practices like Sustainable Manufacturing practices need to be adopted at the earliest possible.

### 3. SUSTAINABLE MANUFACTURING AT GLOBAL LEVEL

Sustainable manufacturing practices are one of the key environmental initiatives and it is generally perceived that implementing sustainable manufacturing will improve environmental performance. One of such attempt was made to attain the Sustainable Manufacturing in product development through consideration of entire life cycle of products mainly focussing on the environmental requirements (Kaebernick, Kara and Sun, 2003). Sustainable manufacturing practices and their relationship with competitive manufacturing outcomes has been examined and the results showed that pollution prevention practices are associated with a decrease in manufacturing cost (Rusinko, 2007). It was observed that any environmentally proactive practice can produce competitive gains (Amrina and Yusof, 2012). This detailed information regarding conversions made during each step can be utilised as a base to plan future improvements by identifying the various areas which need to be improved throughout life cycle of the product. Though life cycle assessment provides various insights of the products, Dufloy et al., (2012) explored some of the drawbacks of life cycle assessment studies considered under various manufacturing steps. Zailani et al., (2012) studied the relationship between eco-design and environmental performance whereas (Green et al., 2012) assessed the impact of supply chain practices on operational, environmental and organizational performance. Ramayah et al. (2013) showed the relationship between green manufacturing practices and manufacturing performance in SMEs.

The performance of the manufacturing processes and products are required to be evaluated with consideration of each aspect of environment, economy, and society to calculate sustainability assessment. One such attempt was made to create stability between technological, societal, economic, and ecological constraints for designing of automobile bodies. This study was mainly focussed on selection of environment friendly material through measurable processes by developing sustainability measurement model (Mayyas et al., 2012). For attaining the sustainability at national or global level, some appropriate decisions are required to be taken at different stages which

can be facilitated through sustainability assessments (Bare, 2014). To quantify and identify the negative effects of manufacturing processes, (Shojaeipour, 2015) developed an automated assessment system with inclusion of environmental benchmarks through consideration of influencer parameters namely emission, waste production, and hazardous materials. This discussion also highlight the area of debate to develop a more detailed investigations for life cycle assessments in order to provide robust decision making at each phase of product life cycle of products (Bhanot, Rao and Deshmukh, 2015).

In general, previous studies are focussed on some of the aspects of sustainability and less of these studies present a simultaneous approach which takes into account the integration of economic, environmental and social aspects of sustainability. Also, there is a lack of studies focussed on the relationship between sustainable manufacturing practices and sustainability performance. According to (Vitousek et al., 1997) manufacturers should consider economic gains along with responsible social and environmental behaviours in order to attain sustainability. Many cases are required to be initiated such as detailed consideration social aspect of sustainability together with economic and environmental aspects and identification various enablers and barriers and their relationship with each other for facilitation of decision making in manufacturing sector.

### 4. SUSTAINABLE MANUFACTURING IN INDIA

According to (Joung et al., 2013) increase in advancement of production technologies to improve the production for satisfying the demand of the increased population through traditional processes will result into harmful effects on the environment through waste and pollutants. These challenges are demanding the development of advanced manufacturing practices which can justify their utilisation through maximisation of economic and societal benefits and minimisation of negative environmental effects. Bhanot, Rao and Deshmukh, (2015) explored the adoption of sustainable manufacturing practices as a complex challenge as most of the organisations are not aware about effective utilisation of drivers and ways to tackle the barriers of SM. Same study was carried out to utilise drivers and tackle barriers by developing framework. These frameworks were then statistically validated through utilisation of structural equation modeling (Bhanot, Venkateswara and Deshmukh, 2017). Srikant and Ramana, (2015) formulated fluids that can replace the regular petroleum based emulsifier with an environment friendly alternative which can be applicable for machining at higher speeds. In one of the study, relationships between various parameters of milling and turning machining processes were generated to examine their interdependencies through application expert systems (Bhanot, Rao and Deshmukh, 2015).

In one of the review, current practices of sustainable manufacturing in gear manufacturing were reviewed which recorded the significant improvements in productivity, cost, tool life, gear quality, energy usage, waste generation and waste management strategies by using environment-friendly lubricants and lubrication techniques such as cryogenic and dry gear hobbing, employing advanced gear manufacturing processes such as gear rolling (Gupta et al., 2016). In one investigation, (Sen, Roy and Pal, 2016) tried to forecast the energy consumption and GHG emission for a pig iron manufacturing organization of India with an aim to know the current and future trends of environmental indicators for better environmental policy. In one of the study of sustainable manufacturing model generation, authors generated innovation-driven sustainable manufacturing model to calculate and evaluate sustainability assessment of various pollution control equipment of manufacturing organisation. They also believe that sustainable manufacturing and innovations can be linked if practitioners and academicians investigate this possible link in detailed manners (Singh and Lal, 2012).

One of the studies related to identification of most impressive and significant enablers and barriers of sustainable manufacturing was carried out to analyse their impacts on organisations. In that study authors identified that foreign direct investment and proper training systems are the most effective enablers for implementation of sustainability in manufacturing sector and lack of awareness amongst industry professionals and lack of proper framework are the most effective barriers which hinders the implementation of sustainability in manufacturing sector (Bhanot, Venkateswara and Deshmukh, 2017). Many authors have considered the fact that the path of implementing sustainable manufacturing is difficult as it demands overcoming various challenges at different level and different stages of manufacturing processes to produce sustainable products and processes.

## 5. CHALLENGES FOR IMPLEMENTATION OF SUSTAINABLE MANUFACTURING IN INDIA

- i. The growth of the Indian manufacturing industries is hindered because they are experiencing a lot of barriers in implementing sustainable manufacturing practices due to dynamic market, scarce resources, lack of in depth knowledge and awareness of such practices (Mathiyazhagan et al., 2013).
- ii. One more constraint especially for SMEs can be untrained workforce related to sustainable manufacturing practices (Mathiyazhagan et al., 2013).
- iii. For manufacturing industries to adopt sustainable manufacturing practices there must be available needs and expectations of customer for green products and processes (Bhanot, Rao and Deshmukh, 2015).

- iv. Due to un-availability of proper government organizations and laws which can motivate the organizations for adopting sustainability practices, there is resistance and un-supportive attitudes due to unawareness of sustainable manufacturing concept (Bhanot, Rao and Deshmukh, 2015).
- v. Involvement high initial investment and low return on investment. In most of the SMEs they don't have enough funds to go for remanufacturing and the involvement of high initial cost makes it tougher for them. So some government policies can be framed for them to motivate sustainability practices (Xia, Govindan and Zhu, 2015).
- vi. For successful adoption of sustainable manufacturing practices it needs continues support and motivation from top management in terms of required resources and infrastructure throughout the project (Amrina and Yusof, 2012).
- vii. Need of upgrading the current infrastructure of power supply to cop up with green requirements by exploring the utilization of renewable source of energy (Bhanot, Rao and Deshmukh, 2015).
- viii. Adoption of sustainable manufacturing practices in manufacturing industries need high credit which is available at higher interest rates which hinders the initiation of such practices (Mathiyazhagan et al., 2013).

## 6. CONCLUSION

The literature review carried out for this paper strictly suggests that environment awareness is absolutely critical to all socially answerable manufacturers. To be competitive on a worldwide scale manufacturing should be lined up with different strict environmental protocols. The manufacturing industry is really trying hard to achieve quality and productivity in their processes through accomplishment of reduced energy consumption, negative environmental effect, greenhouse gases and generation of waste. This can only be attained when manufacturing industries will able to frame the strategies having combined favourable integration of economic, social and environmental aspect of sustainability. It is also to be noted that to attain the integration of these aspects of sustainability, the various stakeholders (Policymakers, Industry, University and Research Institutes) are required to understand their responsibilities and play their role in development & implementation of SM.

The aim of this paper was to provide an insight of the sustainable manufacturing with exploration of various studies carried out national and international level. This paper also discussed how manufacturing sector is crucial for adoption of sustainable manufacturing as well as for stable economic development of the developing nations like



India. It also explores the challenges or constraints which industries are realizing while initiating the environment conscious concept sustainable manufacturing and on the same way it is also indication of opportunities in the area of adoption of sustainable manufacturing if constraints are treated properly. From the above study it was observed that there are evidences for work carried out in sustainable manufacturing but most of the work is carried out in terms of the theoretical, explorative and empirical but less evidence of sustainable manufacturing case studies where implementation of such concept is actually carrying out with taking into consideration of all the aspects of sustainable manufacturing such as economic, environment and social. So this paper clearly indicates the need of implementation of sustainable manufacturing in industries to actually realize its benefits and constraints in India.

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# Impact of Green Manufacturing Drivers on Triple Bottom Line of Small Scale Industries in India

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**Abstract:** Small scale manufacturing industries are essential for industrial development in India. most of the large scale industries are very much dependent on the small scale units. After fulfilling the quality standards laid down by the governments, its time for small industries to switch over from conventional manufacturing to green manufacturing. Green Manufacturing (GM) methods not only minimize waste and pollution but it also led to financial gain if done correctly. GM is responsible for ensuring the product's manufacturing in a benign, harmless manner causing minimal unsympathetic impact on environment by best use of resources. This paper aims to identify GM drivers for small scale Industries in India and to develop conceptual framework based on the identified GM drivers and their impact on triple bottom line using available literature. This paper is also helpful in understanding mutual influences of drivers.

**Keywords:** Green Manufacturing, drivers, critical factors, triple bottom line

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## 1. INTRODUCTION

Manufacturing has emerged as one of the high growth sectors in India. Prime Minister of India, launched 'Make in India' program to place India on the world map as a manufacturing hub and give global recognition to the Indian economy (Sindhu et al., 2016). As per the report of United Nations Industrial Development Organization (UNIDO) India rank sixth among the world's 10 largest manufacturing countries in 2015(Report UNIDO, 2016). India is on the path of becoming the hub for hi-tech manufacturing as global giants such as GE, Siemens, HTC, Toshiba, and Boeing have either set up or are in process of setting up manufacturing plants in India, attracted by India's market of more than a billion consumers with increasing purchasing power.

### Small scale industries

An industry with a low rate of production and fewer employees is a small-scale industry. These are easy to start and manage given the minimal scale of production. Most governments implement policies that strengthen the small-scale industry sector because of the role the industries play in economical development. A small firm is an enterprise where the investment in plant and machinery is more than INR 25 lakh but does not exceed INR 5 crore (Ministry of MSME, 2008; Ministry of MSME, Government of India, 2006). One more term 'micro' industry is also used along with these terms in Indian context. Accordingly these manufacturing enterprises are classified based on plant and

machineries investments. Enterprises having investments of less than 2.5 million rupees (up to 62500\$) are grouped as micro enterprises, 2.5 million to 50 million rupees (625000 to 1.25 million \$) are grouped as small scale enterprises. (Thanki et al, 2016).

### Green Manufacturing (GM)

Green Manufacturing can be applied in all manufacturing sectors that minimize waste & pollution, Enables economic progress and conserve resources(Maruthi & Rashmi, 2015). The process of Green Manufacturing involves investing in production process improvements rather than control technology, substitute renewable sources for finite ones, employee recycling and the companies must decide whether to make or buy the product. According to Alay et al.(2017) GM is understood as the actions, initiatives and techniques that positively affect the environmental, social or economic performance of a firm; helping to control or mitigate the impacts of the firm's operations in the triple bottom line. GM produces economically viable products with minimum environmental and social impact(Thanki et al., 2016) .Thus green manufacturing includes generating processes which utilize inputs with low environmental impact, as well as processes which are profoundly productive with nearly zero waste and contamination(Ghazilla et al.2015).Greening is the process of transformation into a more environmentally friendly version, which has been understood to be linked with strong color often associated with life, fertility and health (Mohanty & Prakash, 2013).GM is responsible for ensuring

the product's manufacturing in a benign, harmless manner causing minimal unsympathetic impact on environment by best use of resources.(Rehman et al. 2016;Srivastava, 2007)

According to (Deif, 2011) GM reflects a new manufacturing paradigm that incorporates various green strategies (objectives and principles), drivers (motives, motivators and critical success factors) and techniques (including technology and innovations) to become more eco-efficient. GM includes making or creating products/systems that consumes less materials, less energy, substituting input materials (non-toxic for toxic, renewable for non-renewable) reducing unwanted outputs, wastes, emissions and converting outputs to inputs (recycling).

There is a fundamental shift in the socioeconomic and environmental landscape, technology evolution, population growth and global awareness regarding the finite nature and rapid depletion of resources (Sandeep Goyal et al 2016). There is a universal realization, albeit at a slow rate, that the Earth is fragile with its carefully balanced ecosystem and natural resources (Gayathri, 2015 ). The consumption-driven cradle- to-grave model involves exploiting the finite resources to create new products and eventually disposing the used products non systematically into landfill sites, which lacks sustainability for the future. Statistically, India produces 62 million tons of solid waste on daily basis. This is equivalent to 3 million truckloads daily. This volume is expected to reach 436 million tons on daily basis by 2050. From 62 million tons of solid waste, only 20% gets treated, with the remainder being dumped in landfill sites (IANS, 2016 ; Mallapur, 2014 ).

The rest of this paper is organized as follows. Section 2 briefly reviews the literature. Section 3 presents the proposed framework for Impact of Green Manufacturing on Triple Bottom Line of Small scale industries in India. Furthermore, discussion is described in section 4. Finally, conclusions are presented in Section 5.

## 2. LITERATURE REVIEW

Due to an increase in energy price, pollution and global warming, along with strict implementation of rules and regulation related to environmental performance, there is an urgent need for Indian Micro, Small and Medium Enterprises (MSMEs) to formulate manufacturing paradigms, such as lean and green, to remain competitive in the globalized market (Thanki et al., 2016).The growing interest in sustainable development offers better opportunities to SMEs than to larger firms due to the fact that SMEs have more adaptable productive structure and major capacity to understand specialized and local markets (Moore and Manring, 2009).Small and medium scale industries have an important role in generating employment opportunities, strengthening industrial linkages, penetrating markets and generating export earnings (International Business Publication, 2007, p. 235).Small and Medium

Enterprises (SMEs) play a vital role for the growth of the Indian economy by contributing 45% of the industrial output, 40% of exports, 42 million in employment and creating one million jobs every year and producing more than 8000 quality products for the Indian and international markets. Because SMEs represent a significant element of the economy, they have a considerable impact on the environment. Individually, SMEs may have limited impact on the environment, but collectively, their impact is believed to be significant (Chiu et al., 1999).

In both developed and developing countries, SMMEs, and in particular small and micro enterprises, account for the vast majority of enterprises. For example, approximately 97% of enterprises in Mexico and Thailand fall into the small and micro category, and over 96% of enterprises in the United-States have fewer than 50 employees.² Because developing countries are typically more focused on small-scale production, the share of overall employment by small and micro enterprises tends to be higher. Studies in five African countries found that these small scale businesses generate nearly twice the level of employment that registered large scale enterprises and the public sector do.(Mead, & Liedholm, (1998).However, small and medium enterprises (SMEs), in particular, are often unaware of their impact on the environment and lack the knowledge and expertise needed to implement and manage EMS (Ortiz et al., 2013). These companies have exerted significant pressure on the environment, either individually or through a combination of sectors. For example, the SMEs in Europe have been responsible for approximately 64% of the region's industrial contamination (DG Enterprise, 2010). This context has heightened the need to implement systems for monitoring and promoting improvements in the environmental management performed by SMEs.

There is lack of concern towards to environment by SSIs in India. Through the research in the SSIs in India it is stated that there is lack of demands from local customers and government on greening the product, so the pressure from these two parts can drive the industries for developing green products and production.Small scale industries in India are need of a sustainable development, so the awareness and demands of green products must be encouraged.Fresner and Engelhardt(2004) present and analyse two case studies that demonstrate that real experiences in improving environmental and economic performance by improving processes and procedures occurred and motivate the company's leadership, suppliers and employees to continue to make additional improvements. .Zhu et al. (2008) pointed out that stricter government regulations and increased community and consumer pressures have raised the need for the manufacturers to effectively integrate environmental concerns into their regular practices and onto their strategic planning agenda.Wooi and Zailani (2010) investigated the

barriers that hinder the SMEs in Malaysia from implementing green supply chain and found that resources barrier is the key barrier that impedes the adoption of GSCM initiative and the technical barrier is expected to be the key barrier for the SMEs in the manufacturing sectors in Malaysia. Cuerva et al. (2014) about the main drivers of eco-innovation in small- and medium-size enterprises (SMEs). analyze the differences between the factors influencing “green” and/or “non-green” innovations for SME in a Low-Tech sector based on quantitative analysis. The main purpose of this study is to analyze the factors influencing the adoption of green and broad innovations in small- and medium-size enterprises (SMEs) in a specific sector. SMEs are not only increasingly adopting codes of conduct covering environmental aspects but also integrating working conditions and human rights. Rosen and Kishawy (2012) highlighted the need for integrating sustainability principles with manufacturing and design along with important objectives like profitability, competitiveness, function, and productivity. A company in Europe is considered a SME if it has fewer than 250 employees and an annual turnover not exceeding 40 million EUR (EC, 2003). In the Philippines, the most common categorization method for SMEs is based on a company’s asset size or number of employees, being much smaller than the operations of multinational companies (Rao et al., 2006). Several studies about the implementation of

environmental management in SMEs have been performed around the world in recent years (Hillary, 2004; Seiffert, 2008; Govindan et.al (2012); Zorpas, 2010; ). small-scale industries often have major problems with limited resources, limited knowledge, and limited technical capabilities to deal with their own negative environmental impact. SMEs exhibit widely differing characteristics and commitment where environmental issues are concerned Parker et al (2009). Cleaner production is an effective approach to analyse the productive processes. It aids to reducing use of chemicals and generation of waste and emissions Fresner and Engelhardt (2004). Studies done in small scale industries context have focused on wide range of topics such as regulations and financial incentives (Studer et.al 2008; Zorpas, 2010; Claver et.al 2007), environmental awareness and training (Aragón-Correa, et.al, 2008; Cloquell-Ballester et. al, 2008), Green design and process (Gurbuz et. al, 2004; Singh et. al, 2012) Most of the literature focuses on limited aspects of GM, however in case of small scale industries very few studies deals with Financial Incentives/ assistance, Fines due to non compliance of regulations Strategic and organizational changes, General competitive, Upgraded control measures, Innovation capabilities . Strategic and organizational changes, General competitive Top management leadership / commitment, stakeholder involvement (Figge & Hahn 2012, Neto et.al 2016, Shen & Tam, 2002, D’Souza 2001),

**TABLE 1: Identified GM drivers for SME**

	Environmental Regulation/Legislation	Fine	Financial Incentives/	improved Cleaner production,	Strategic and organizational changes,	Top management leadership/	stakeholder involvement	Reduced emission, waste,	customer satisfaction and quality	process, packaging and 3R	Low energy consumption	Environmental awareness,	Upgraded control measures,
Parker et al (2009)	√		√									√	
Gurbuz et al (2004)				√									
Studer et.al (2008)	√				√								
Fresner & Engelhardt (2004)				√		√	√						
Thanki, et al. (2016)	√						√	√	√	√			
Aragón-Correa, et.al (2008)					√		√						√
Hillary. (2004).													
Zorpas (2010).	√											√	
Claver, et.al	√				√		√	√					

	Environmental Regulation/Legislation	Fine	Financial Incentives/	improved Cleaner production,	Strategic and organizational changes,	Top management leadership/	stakeholder involvement	Reduced emission, waste ,	customer satisfaction and quality	process, packaging and 3R	Low energy consumption	Environmental awareness,	Upgraded control measures,
(2007).													
(Singh et al.(2012)										√			
Cloquell-Ballester et al.(2008),			√									√	
Dayaratne & Gunawardana (2015)								√			√		
Lee(2009)					√								√
Govindan et.al (2012)										√			
Figge & Hahn (2012)	√	√					√						
Neto et.al (2016)	√		√										
Chan & Li (2001)													
Shen & Tam, (2002)	√				√	√	√						
D'Souza (2001),	√				√	√							

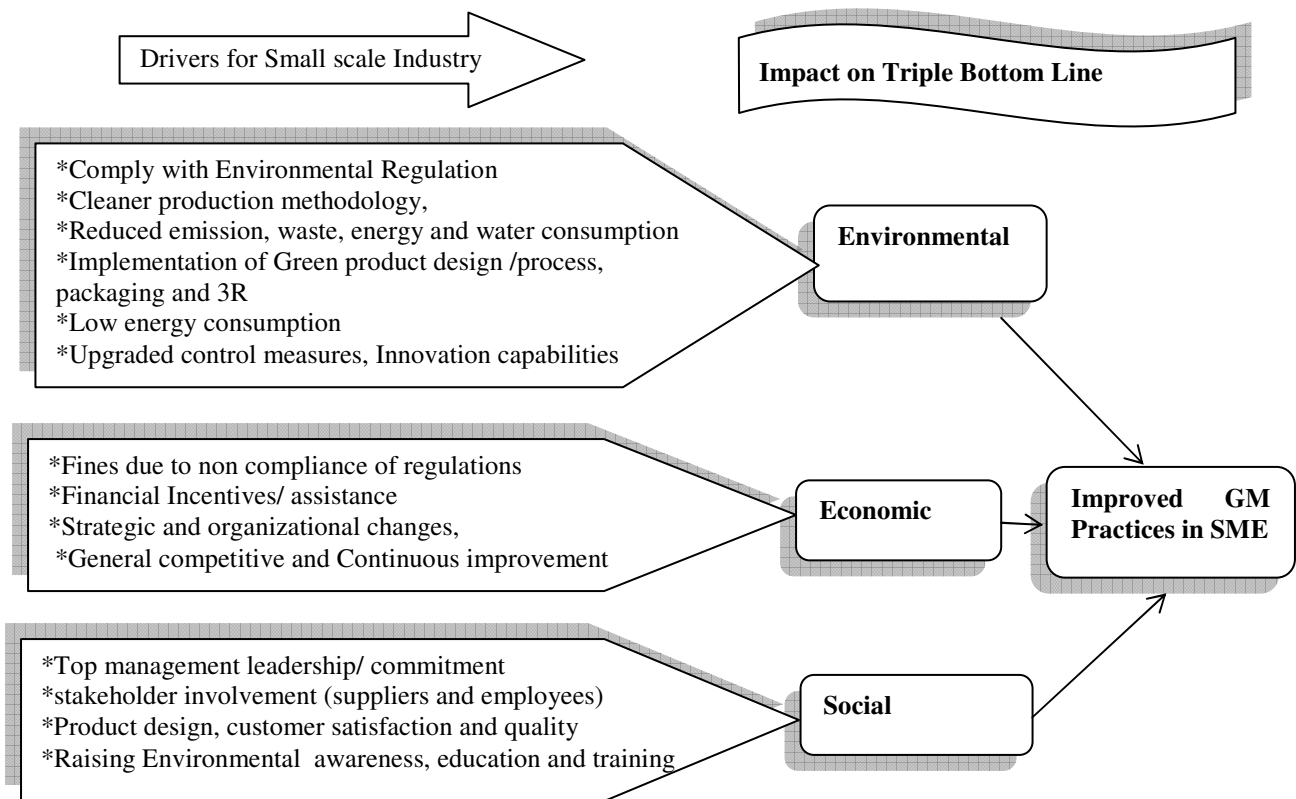
Based on above literature review, the authors are attempting to document GM drivers for SMEs, With respect to the triple bottom line aspects Viz.Environmental, Economic and Social

- Comply with Environmental Regulation/Legislation (Environmental aspect)
- Improved Cleaner production methodology, (Environmental aspect)
- Reduced emission, waste, energy and water consumption (Environmental aspect)
- Implementation of Green product design /process, packaging and 3R (Environmental aspect)
- Low energy consumption and efficient Energy management (Environmental aspect)
- Upgraded control measures, Innovation capabilities (Environmental aspect)
- Fines due to non compliance of regulations(Economic aspect)
- Financial Incentives/ assistance(Economic aspect)

- Strategic and organizational changes, (Economic aspect)
- General competitive and Continuous improvement(Economic aspect)
- Top management leadership/ commitment (Social aspect)
- Stakeholder involvement (suppliers and employees) (Social aspect)
- Product design, customer satisfaction and quality (Social aspect)
- Raising Environmental awareness, education and training (Social aspect)

### 3. PROPOSED FRAMEWORK FOR IMPACT OF GREEN MANUFACTURING ON TRIPLE BOTTOM LINE OF SMALL SCALE INDUSTRIES IN INDIA

Based on the literature review, the proposed framework for Impact of Green Manufacturing on Triple Bottom Line of Small scale industries in India are as shown in Figure1



**Fig. 1. framework for Impact of Green Manufacturing on Triple Bottom Line of Small scale industries in India**

#### 4. DISCUSSION

Through extensive literature review a total 14 drivers of GM for Small scale industries in India are identified. These drivers are grouped in to three major criteria's as **Environmental, Economic, Social** (Triple Bottom Line)..Indian companies will have to follow GM practices and demonstrate commitment to green philosophy(Rehman et. al, 2013). Successful GM implementation cannot survive on the basis of small standalone initiatives. For successful implementation of GM, the industry captains and policy makers need to treat green as a part of business strategy, execution of green across the entire value chain including energy, resources, raw materials and procurement practices, products and processes and ensuring the transfer of benefits and promotion of green initiatives to the stakeholders. Indian manufacturing industries are shifting forward from "green conformance to green performance" and are serious towards comprehensive GM rather than just pollution prevention (Rehman et al., 2016). It is expected that if GM is applied in a systematic manner after understanding its drivers, will reduce the GM implementation efforts and hassles. It will also offer strategic benefits, like cost savings resulting from eco-efficiency, enhanced corporate image, improved relationships with communities, access to green markets and superior competitive advantage

#### 5. CONCLUSION

Indian SME sector plays an important role in nation development and is treated as vibrant sector of Indian economy. In Indian context, SMEs offer a large employment opportunities at relatively lower capital costs than large industries and also help in industrialization of rural areas.The present study effectively touches all the three important aspects of triple bottom line and having greater implications on environmental, economic and social aspects. As shown in figure 1 small scale industries are having strong implication on environmental, social and economic aspect .The reason may be the corporate social responsibility and laws imposed by government or after achieving milestone it may be voluntary move.The only way to minimizing the environmental impact of small scale manufacturing is to implement GM .To facilitate this, the authors had identified various GM drivers for small industries. This paper proposed framework for impact on triple bottom line by various GM drivers and smooth the progress of prioritizing this drivers for small scale industries.

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# Sustainable Machining: A Review

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**Abstract:** Sustainable manufacturing as a global word, content important elements on the field of machining processes. Today's global scenario where the sustainability of manufacturing processes in critical consideration for competitiveness, it is essential to improve machining processes and also effect of manufacture on the environment. In view of this, this paper present the systematic review of existing literature on sustainable machining, aim to providing proper understanding and guidance on the topic, and finding several new path for research on sustainable machining. The paper reveals that the fact about machining process and its parameter towards sustainability.

**Keywords:** Sustainable Machining, Sustainable Manufacturing

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## 1. INTRODUCTION

Sustainable development should be considered as a universal goal for industrial organization. Industry is becoming to feel higher pressure as a response to the competitive market. At the beginning of the 21st century, there are increasing sustainability concerns oriented on nation developing activities and the industrialized world (Pusavec F., Kopac J., 2009). Adopting sustainable manufacturing in practices offers metal machining companies, a cost effective route to improve their sustainability performance.

Conventional metal machining processes are more dangerous impact on environment. And also environment affected by use of conventional lubrication system. Using large quantity of lubrication leads to difficulties in procurement, disposal, storage and maintenance.

As a result use of unconventional cooling/lubricant systems such as minimum quantity lubricant (MQL), cryogenic coolant, solid lubricants, Gaseous cooling, Sustainable cutting fluids, Nano fluids etc. for moving towards sustainable machining. And also reduce the use of high rate cutting fluids. Sustainable manufacturing main aims to develop a most suitable methods to convert raw materials into final products by eliminating or reducing the consumption of natural resources and energy. However the integration of environmental requirements into the every stage of manufacturing, leading to a sustainable manufacturing process.

It is essential to improve production rate, cutting quality and also effect of manufacture on the environment. There are need to introduce environmental requirements into the manufacturing process. The sustainable manufacturing are great deal with Environment, Economical and Societal requirements. The United Nations defines sustainability as 'Development that meets the needs of the present without

compromising the ability of future generations to meet their own needs' (Laubscher et al. 2016).

### 1.1 What is Sustainable Machining?

Sustainability has many definition and various interpretation in the field of manufacturing. Many authors have attempted to interpret and explain the meaning of sustainability in their own way, However According to US Department of Commerce, sustainable manufacturing is defined as 'The creation of manufactured products using processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound (Zhao et al. 2013). The Sustainable manufacturing of products are developing and establishing energy efficient, non-polluting, economical, and viable processes for manufacturing of products (Gupta et al 2016).

The implementation of Sustainable machining processes or techniques to ensures the Environmental, Economical and societal improvement in terms of machining operation.

The implementation of sustainability principles in machining practice, the machining industries have potential to save money and improve their environmental performance even though the production stays in the same range or it is shrieked (Kopac et al 2009). The sustainable machining improve the environmental impact of existing manufacturing processes and develop new concepts.

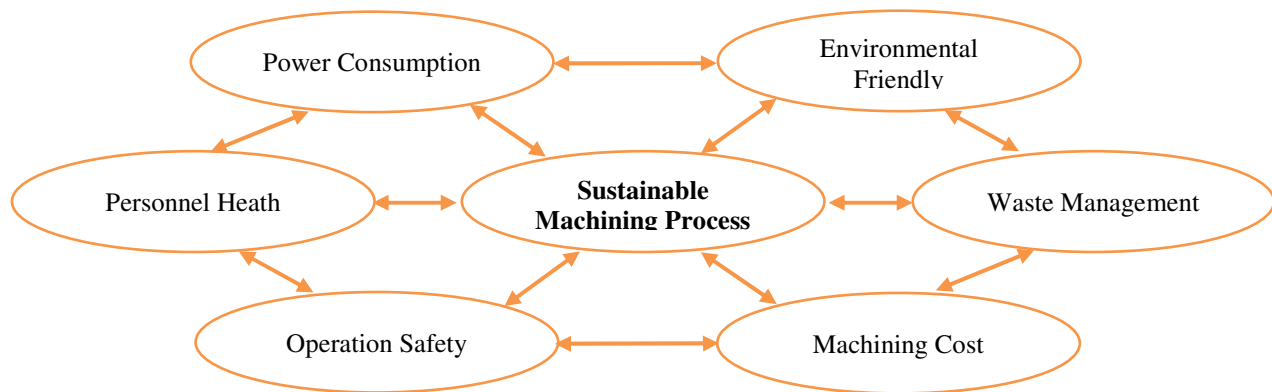
### 1.2 Why Sustainable Machining is required?

The implementation of sustainable machining is required for, to survive in competitive market. Sustainable machining gives lower energy consumption and lower material cost with minimum environmental impact of machining processes. The sustainability performance of industries can be improved by:

- Minimizing waste of machining process.
- Less waste generated and increase waste recycle.
- Using resources more efficiently.
- Improved environmental, health and safety performance.
- Adopting sustainable engineering techniques.
- Improve working conditions, using best practice in machining.

## 2. SUSTAINABLE MACHINING

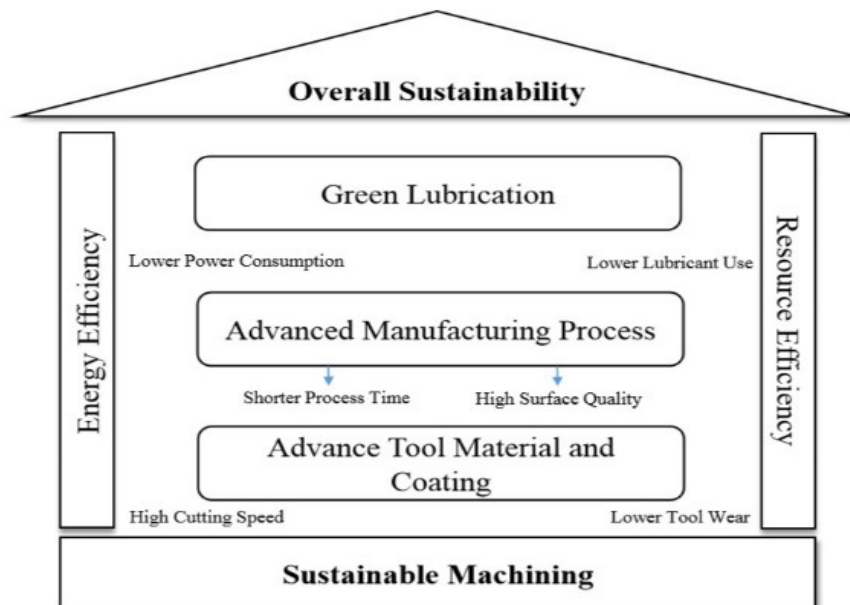
Sustainable machining can be defined as the manufacture of products by a subtractive process based on material removal by the cutting action of a tool usually with a machine tool to create surfaces and features in a way that is reduce waste and environmental impact. Nowadays more important become environmentally and health benign technologies and advanced technique for achieving cleaner, healthier, safer and economical machining process (Pusavec F. & Kopac J., 2009). Sustainable machining deals with environmental friendly, power consumption, personnel health, operation safety, machining cost waste management.



**Fig. 1. Sustainable Machining Process.**

To improved sustainability performance during machining is attained by:

- To improved sustainability performance during machining is attained by:
1. Selecting the optimum machining parameter to minimize power consumption and to maintain cost efficiency
  2. Selection of proper cutting tool materials, geometries, and coatings to improve tool life and part quality.
  3. Selecting the advanced lubrication system such as MQL, solid lubricants, Nano fluids, Sustainable cutting fluids and cryogenic cooling to minimize the cost associated with lubrication system.



### Fig. 2. Sustainable Machining

### 3. LITERATURE REVIEW

Nowadays, the most efficient way to carried out research is by Internet. Various sources are available for search the paper. But Science Direct is used for search the quality research papers. The keywords used for search the paper is Sustainable Machining. However, the result appeared from

many different area. So twenty nine articles were collected, which included Sustainable machining of Milling operation, Turning operation, Electron beam machining, Electron discharge machining and Advanced Lubrication system such as Minimum Quantity Lubrication (MQL), Cryogenic cooling, solid lubricants.

**TABLE I: Literature review on sustainable machining.**

Sr. No	Author and Publication year	Sustainability Aspect Consideration	Contribution
1	Mozammel Mia (2017)	Sustainable Machining and Cryogenic Cooling	The Cryogenic cooling by liquid nitrogen is more effective than dry cutting and conventional cutting oil and improve machining responses such as lower cutting force, surface finish and reduced specific cutting energy.
2	Wu et al. (2017)	Machining Parameter Optimization	The study shows that Energy Consumption and Machining cost can easily select the optimal tool sequence to reduce energy and save cost CNC milling process.
3	Zhang et al. (2017)	Machining Parameter	While machining of steel, The cutting forces increase with the increase of feed rate And cutting temperature rises with the increase of cutting speed.
4	Ibrahim et al.(2017)	Cryogenic and Wet machining	The Cryogenic coolant CO2 provide up to 6 times increase in tool life Compared to conventional Emulsion Within the range of data.
5	Ganguli et al. (2017)	Atomization Based Cutting Fluid	ACF spray system is able to extend tool life as 75% over flood cooling at appropriate level of Feed and Depth of Cut and able to formation of Shorter and thinner chip as compared to flood cooling.
6	Benedicto et al. (2017)	Cryogenic and Dry machining, Minimum Quantity Lubrication	MQL system reduces the fluids use, economic and environmental impact and also improve the performance. Cryogenic cooling enhance the tool life.
7	Li et al. (2017)	Machining Parameter and Energy Consumption	The effective reduction of the total tool path and cutting length as compared with parallel milling and streamline milling.
8	Pereira et al. (2017)	Minimum Quantity Lubrications	The study show that the combination of low viscosity with high friction coefficient implies an increase in tool life.
9	Goindi et al. (2017)	Minimum Quantity Lubrications	MQL assisted machining has proved to be very effective and also Improved Tool life and Surface Quality.
10	Uhlmann et al. (2017)	Sustainable Machining	To increase productivity and material removal rate, the spindle speed increaser is effectively used. It can help to increase the removal rates and thereby to save machining time.
11	Vakkas et al. (2017)	Sustainable Machining, Minimum Quantity Lubrications	The main factor affecting tool life and cutting force was flow rate. Vegetable-based cutting oil gave higher tool life.
12	Boswell et al. (2017)	Minimum Quantity Lubrications	The addition of nanoparticles into MQL cutting fluid has more ability to improve lubrication system.
13	Singh et al. (2017)	Bio lubricants	Non-edible vegetable oil based bio-lubricants have enhanced lubricity, high viscosity, good anti-wear property, low emission of metal traces into the atmosphere.
14	Liu et al. (2016)	Sustainable Manufacturing	Specific Energy decrease when process parameter increase.

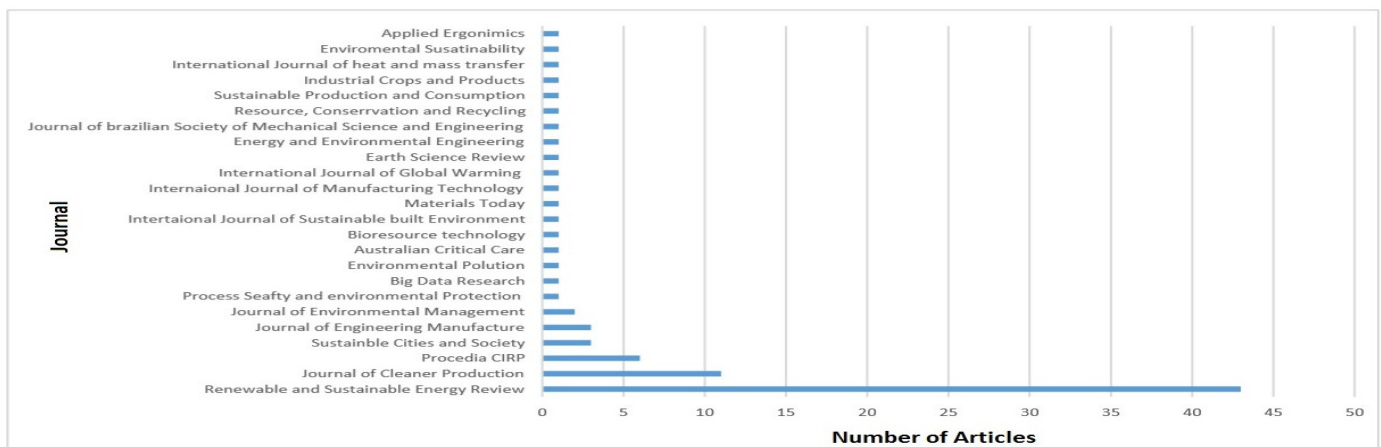
Sr. No	Author and Publication year	Sustainability Aspect Consideration	Contribution
			Higher MRR Results in less total specific energy and environmental impact.
15	Putz et al. (2016)	Sustainable Machining	Experiments reveals that pressurized cool air could be a solution to reduce the Tool Center Point displacements and also improve the accuracy of parts machined by fine turn-milling operations.
16	Thakur et al. (2016)	Minimum Quantity Lubrications	The study revealed that dry machining using coated tool over flood cooling and MQL was more prominent under finish mode.
17	Kumar et al. (2016)	Minimum Quantity Lubrications	The machining performance of high velocity solid lubricant jet is better that that of wet, dry and MQL machining. It provides benefits by reducing the cutting temperature.
18	Gupta et al. (2016)	Sustainable Machining	Al ₂ O ₃ , and AlCrN are used as coating material that minimize tool wear and increase tool life.
19	Jomaa et al. (2016)	Sustainable Machining	The peripheral milling process to produce good surface roughness under dry conditions
20	Owodunni et al. (2016)	Sustainable Machining	The higher material process rate leads to reduction in specific energy consumption.
21	Simunovic et al. (2015)	Cooling/lubrication, Dry cutting conditions	Applicability of dry cutting is possible for small surface or short term machining while for longer term machining cooling and lubrication through the tool applied.
22	Wang et al. (2015)	Minimum Quantity Lubrications	The optimum cutting parameters determined by surface roughness. MQL works effectively with up milling.
23	Liu et al. (2015)	Sustainable Manufacturing	Material Removal Rate (MRR) is a unique identifier for total power and spindle power. Energy efficiency increase with MRR.
24	Carvalho et al. (2015)	Machining Parameter	The wear of the insert decreased even as the life of the new tool increased and also improve in quality.
25	Sharma et al. (2015)	Nanoparticule Enriched Minimum Quantity Lubrication	The study reveals that in Nano fluid machining, higher nanoparticle concentration yields better surface finish and more lubrication compared to dry machining.
26	Mulyadi et al. (2015)	Minimum Quantity Lubrications	The use of MQL environment significantly improve the machining performance in respect of tool life.
27	Aramcharoen et al. (2014)	Cryogenic machining and Sustainability	The cryogenic cooling significantly reduced the temperature in the cutting zone. Cryogenic cooling helps to improve sustainability in the cutting process.
28	Yan et al. (2013)	Sustainable Manufacturing	The experiment result Shows that multiple response such as Material Removal Rate (MRR), Surface quality and energy saving can simultaneously improve by multi-objective optimization.
29	Fratila et al. (2011)	Sustainable Machining and Minimum Quantity Lubrication	The use of MQL can be successfully applied without affecting the Machining Parameter. Surface Roughness and Cutting power are mostly affected by Process parameter (Cutting Speed, Feed, Depth of Cut)

The literature review reveals that various parameters are considering during sustainable machining. The lubrication system, cutting conditions and energy use are most important to improve sustainability. This table provides the overview of sustainable machining and advanced lubrication systems.

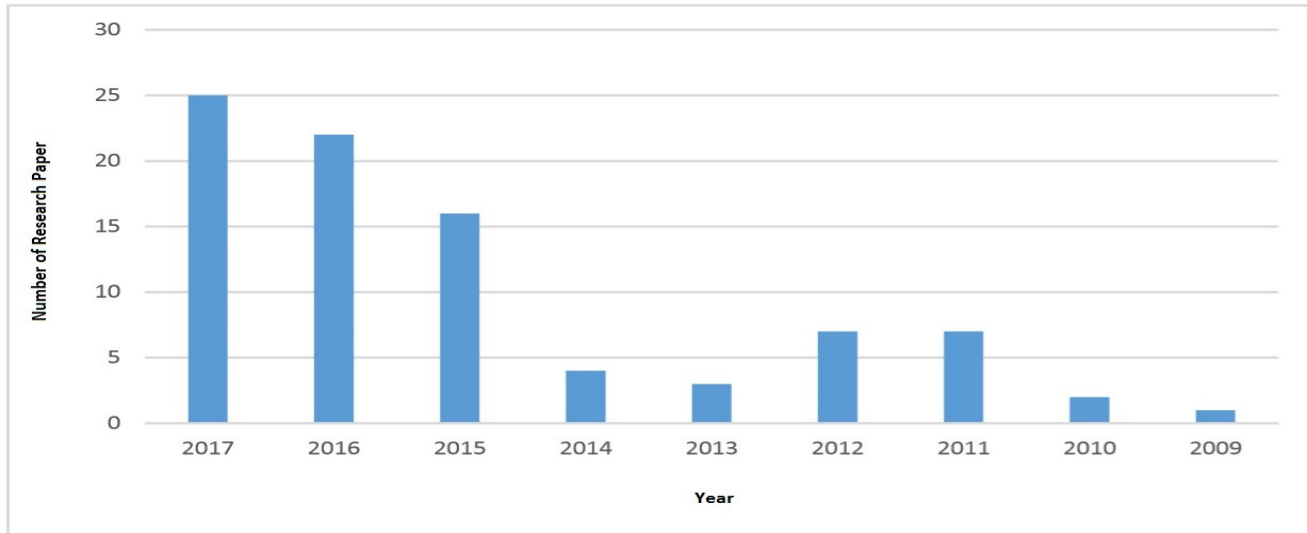
**TABLE II: Distribution of reviewed paper in various journals.**

Name of the Journal	No. of Paper	%
Renewable and Sustainable Energy Review	43	50
Journal of Cleaner Production	11	12.79
Procedia CIRP	6	6.97
Sustainable Cities and Society	3	3.48
Journal of Engineering Manufacture	3	3.48
Journal of Environmental Management	2	2.32
Process Safety and environmental Protection	1	1.16
Big Data Research	1	1.16
Environmental Pollution	1	1.16
Australian Critical Care	1	1.16
Bio resource technology	1	1.16
International Journal of Sustainable built Environment	1	1.16
Materials Today	1	1.16
International Journal of Manufacturing Technology	1	1.16
International Journal of Global Warming	1	1.16
Earth Science Review	1	1.16
Energy and Environmental Engineering	1	1.16
Journal of Brazilian Society of Mechanical Science and Engineering	1	1.16
Resource, Conservation and Recycling	1	1.16
Sustainable Production and Consumption	1	1.16
Industrial Crops and Products	1	1.16
International Journal of heat and mass transfer	1	1.16
Environmental Sustainability	1	1.16
Applied Ergonomics	1	1.16
<b>Total number of Paper</b>	<b>86</b>	<b>100</b>

Total 86 research papers reviewed from 24 international journals over period of 2009 to 2017.



**Fig. 3. Number of Articles published in various journals and conferences.**



**Fig. 4. Year wise distribution of Articles published.**

The graph shows that trend of Sustainable Machining over the year. Which shows the trend of publication from 2009 with 1 publications only to 2017 with 25 publications.

#### 4. CONCLUSION

From the literature review, it can be stated that the increasing worldwide trends in achieving sustainable machining and sustainable lubrication system. The literature review reveals that implementation of sustainable machining, reduce the environmental impact and led to society towards sustainable development. It also reveals that the use of sustainable lubrication such as Minimum Quantity Lubrication (MQL), Cryogenic cooling, Gaseous cooling, Nano fluids and Solid Lubricants etc. are reduced the energy consumption and improve surface integrity and it is also lead towards social impact by considering the safety of employees, healthier working environment.

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# Currency Notes Wastage Processing and Utilization Techniques Towards Green Manufacturing in Indian Economy

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**Abstract:** The usual disposal for currency printing waste is incineration resulting in air pollution. But, we recycle / reuse, the waste currency notes over its use in incineration thus saving equivalent natural resources and this waste is converted to useful product. We manufacture Recycled Board from misprinted/soiled currency note which is used as a substitute of wood. The world's annual consumption of plastic materials is increasing at a very high rate day by day. Packaging constitutes the largest single sector of plastics use in the world. There are about 50 different groups of plastics, with hundreds of different varieties. Plastic production involves the use of potentially harmful chemicals. Many of these have significant impact on human health. In addition, plastic manufacturing requires other resources such as land and water, and produces waste and harmful emissions. Plastics are generally non-degradable; they take a long time to break down, possibly up to hundreds of years. Waste management methods such as landfill disposal, incineration and improper recycling do not contribute to proper disposal of plastic waste.

This paper explores the potential of currency waste utilization towards environmental protection in India.

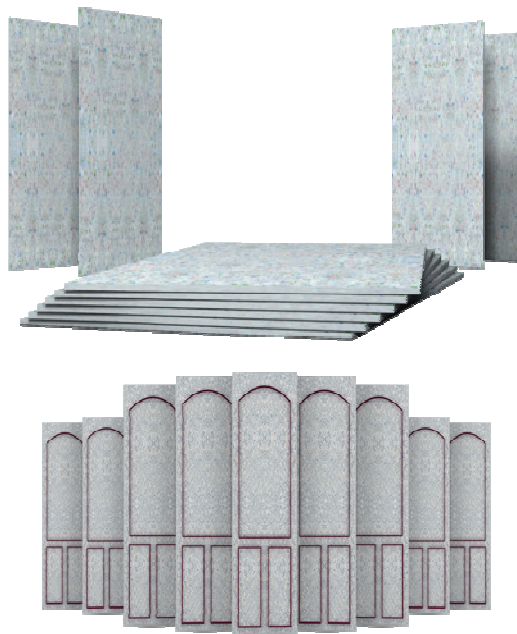
**Keywords:** Currency verification and processing system (CVPS), biotechnology in processing of shredded currency waste, environmental status global warming and solid waste disposal.

## 1. INTRODUCTION

The enormous increase in the quantum and diversity of waste materials generated by human activity and their potentially harmful effects on the general environment and public health, have led to an increasing awareness about an urgent need to adopt scientific methods for safe disposal of wastes. While there is an obvious need to minimize the generation of wastes and to reuse and recycle them, the technologies for recovery of energy from waste can play a vital role in mitigating the problems. Besides recovery of substantial energy, these technologies can lead to a substantial reduction in the overall waste quantities requiring final disposal, which can be better managed for safe disposal in a controlled manner while meeting the pollution control standards.

A report of Central Bank Best Practices: Banknote Destruction, Disposal, and Recycling - stresses innovations and efficiencies in banknote destruction and possibilities for disposal, with emphasis on environmental friendliness, i.e. going green. In particular, incineration and recycling - in the broad sense of these terms - of both paper and polymer banknotes respectively are strongly recommended. Landfill disposal is strongly discouraged. Several suppliers have developed and offered solutions that may facilitate the transition to more environmentally friendly practices. Some Governments and Central Banks have adopted best

practices. Other Central Banks have encountered problems in doing so and do not have recycling programs in place. These banks and other entities in the same situation are encouraged to embrace the recommendations in the manner best suited to the needs of their particular environments.







## 2. ENERGY REDUCTION POTENTIAL

Energy consumption is reduced by recycling, although there is some debate concerning the actual energy savings realized. The EIA claims a 40% reduction in energy when paper is recycled versus paper made with unrecycled pulp (Energy Information Administration, 2006). While the Bureau of International Recycling, BIR, claims a 64% reduction. Some calculations show that recycling one ton of newspaper saves about 4, 000 KWh of electricity. Recycling paper to make pulp may actually consume more fossil fuels than making new pulp via the Kraft process, however, since these mills generate all of their energy from burning waste wood (bark, roots) and byproduct lignin. (Jeffries, 1997). Pulp mills producing new mechanical pulp use large amounts of energy; a very rough estimate of the electrical energy needed is 10, 000 mega joules (MJ) per tones of pulp (2500 KWH per ton), (Biermann & Christopher, 1993). usually from hydroelectric generating plants.

Consumers must be at least provided with re-issuable notes. The notes identified for disposal were shredded and made into briquettes weighing about 100 Gms. The present system has not only prevented environmental pollution but also helped in manufacturing of eco friendly products. Until 2001, the soiled and torn currency notes that were taken back were incinerated. The briquettes are sold for industrial use through tenders. A kg of such briquettes are sold for a minimum of Rs.6. On an average, nearly 8.28 lakh kg briquettes are manufactured every year. The shredded currency is recycled into various products, including files, calendars and even paper weights. Such briquettes are also distributed as souvenirs to the visitors at the stalls of RBI in exhibitions. More people must come forward to make eco friendly products using shredded currency.

## 3. DAMAGED BANKNOTES POLICY ADOPTED BY THE RESERVE BANK OF AUSTRALIA: A NOVEL INITIATIVE

The Reserve Bank of Australia aims to have only good quality banknotes in circulation. This helps to maintain confidence in Australia's currency by making it easier for people to check the security features on banknotes and make it more difficult for counterfeits to be passed or remain in circulation. The Reserve Bank works with authorized deposit taking institutions (ADIs) and cash

centre operators to remove damaged banknotes from circulation as soon as practicable. The Reserve Bank provides a Banknote Sorting Guide to assist with this process. The Reserve Bank provides a Damaged Banknotes Facility to ensure that holders of Australian banknotes do not face financial hardship in the event that their banknotes are accidentally damaged. Given the nature of the Damaged Banknotes Facility, it is important that the Reserve Bank establishes procedures to balance the competing priorities of providing an efficient claims handling process while reducing the risk that the Facility could be used for criminal purposes.

## 4. THE NAVSARI AGRICULTURE UNIVERSITY (NAU) IN GUJARAT MAKING CURRENCY NOTES LASTING FOR ABOUT A CENTURY IN INDIA

The Navsari Agriculture University (NAU) in Gujarat has standardized a process of manufacturing high value paper from Banana fiber, which it claims has the property of making currency notes lasting for about a Century. The paper has been tested in the Central Institute for Research on Cotton Technology. During the research, it was found that paper made out of this fiber has shelf life of over 100 years as it is the strongest of the long fibers ever found amidst natural fibers. It can be folded for as many as 3, 000 times. This fiber has the potential to find application in making of the paper required for the printing of currency notes and other valuable documents. At present Japan uses Banana fiber to manufacture the paper required to print its currency Yen. The commercial application of Banana fiber is viable as its availability is not a constraint. It is generated from stem of the plant which usually goes as waste and has no other application. From one hectare of Banana cultivation about 600 to 800 kilogram of fiber shall be available. The university has filed five different patents from various usage of Banana plant, which includes making of yarn for textiles, paper and candy. The NAU has submitted the findings of its research on Banana plant to the National Agriculture Innovation Project (NAIP), quoting the reference from journals on Japan using Banana fiber to manufacture its currency Yen.

Banana is one of the most important fruit crops grown in India. After harvest of fruit, huge quantity of about 60 to 80 tons per hector of waste biomass (pseudostem, leaves, suckers etc.) is generated. Presently, this biomass is discarded as waste. Present project envisages development of effective value chain for efficient utilization of each and every component of banana pseudostem. Considerable work has been done in the field of direct use and product development from banana fruits. However, not much attention has been focused on effective utilization of the huge biomass generated in the form of pseudostem, leaves, suckers etc.

In India, presently this biomass is dumped on roadside or burnt or left in situ causing detrimental impact on

environment. Though, the technologies for extraction of fibers and paper making from pseudostem are available, yet it has not been adopted by the industries mainly due to high transport cost. However, there exist a vast potential of extracting fibers from pseudo stem. The quantity and quality of fibers show wide variability with cultivars. The fiber extracted from banana pseudostem could not command proper market owing to its restricted use in cottage industries. There appears to be good scope of profitable use of this fiber in textile and paper industries on commercial scale.

## 5. CONCLUSIONS

The continuously growing paper manufacturing industry imposes a severe demand on green plants that forms the basic raw material of papermaking. Woody and non woody plants are major sources of raw material for making paper. In mill sector, woody perennial trees (hard wood and soft woods) are mainly utilized for papermaking. Apart from these plants, rice straw and wheat straw are also the alternative raw materials for paper industry but the quality of these straw papers is very poor. Due to the increased literacy rates, the use of paper is also increasing day by day and thereby resulting into the higher demand of paper in the country. So the ultimate effect is reflected on the wood-based raw materials i.e. green cover or the forest area of the country. Recycling of used paper is another alternative that can liberate this stress from forest and the environment which gets affected due to the usage of large amount of chemicals in processing of the woody raw materials for making paper. Thus, utilization of biotechnology in processing of shredded currency waste would help in improve in the environmental status of the Indian handmade paper industry besides addressing the problem of global warming and solid waste disposal.

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# A Literature Review on Drivers and Barriers of Green Manufacturing in Indian / Global SME's

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**Abstract:** In present days green issues are more important in present contemporary globalization. There more understanding of manufacturing processes due to social and environmental points present. Small and medium enterprises are the major role player in the economic growth in all countries. The implementation of green manufacturing concept in SMEs is the necessity of the present scenario. Literature study shows that there are many areas lefts, to do more for the drivers and barriers of green manufacturing in SMEs. One pilot study was conducted to identify the drivers and barriers in SMEs, which was helpful to identify the research gap. Aim is to determine the success key factors and their relative importance which will provide the organizations to identify the drivers for successful and sustained execution of green manufacturing methodology.

**Keywords:** Green Manufacturing, Small and Medium Enterprises, Key success factors, Drivers and Barriers

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## 1. INTRODUCTION

### 1.1 What is Green Manufacturing?

Today the available resources, compare to population are very much in shrinking mode. Effects on Environment and climate change leads to crucial situation of our earth. There is a requirement of new quality control and management system that also preserve the environment and such has been proposed by ISO too. The main aim is to reduce the environmental damage due to industries and its policies. There is a need of new manufacturing process i.e. Green Manufacturing which can by suitable to a sustainable development (Tan ., et.al, 2002). Fuel charges are increasing and resources are decreasing that lead to high demand and limited supply.

### 1.2. What are Small and Medium Sized Industries?

SME sector is considered as a major economical player in growth in all countries. These provide jobs, act as supplier of goods and services and giving services to suitably larger organization. SMEs are defined by a number of factors and criteria, such as location, size, age, structure, organization, number of employees, sales volume, worth of assets, ownership through innovation and technology (Rahman, 2001). In manufacturing sector, SMEs works as manufacturing and supplier of customized components, parts, and sub-assemblies to larger companies because the items can be produced at a cheaper price than the large companies could achieve in-house. But if quality of product cannot be supply then that make adverse effect the competitive ability of the larger organizations. Mainly SMEs have simple systems and procedures, which allows flexibility, immediate feedback, short decision-making chain, better understanding and quicker response to customer needs than larger organizations. This Study will

try to focus on different issues related with the competitiveness through review of literature to identify the directions for future research on strategy development by SMEs.

## 2. LITERATURE

### 2.1. Literature for Green Manufacturing

Environmental effects are considered as important for business operations with the aim to reduce costs and develop quality products Atasu et al., (2008); Kleindorfer et al., (2005). Green manufacturing spans from product development to management of the entire product life cycle involving such environmental practices as green design, cleaner production, recycling, and reuse with a focusing on minimizing the expenses associated with manufacturing, distribution, use, and disposal of products Lai and Wong, (2012); Guide and Van Wassenhove, 2001; Kleiner, (1991). Green management literatures, green manufacturing is mainly focused on both product- and process-oriented environmental practices Ferguson and Toktay, (2006); Gilley et al., 2000; Rogers and Tibben-Lembke, (2001) to reduce the damage of products and supply chain processes on natural resources Dechant and Altman, (1994); Porter and van der Linde, (1995a, 1995b). In product management, green manufacturing emphasis on quality and environmental conformance, preventing negative corporate reputation by environmentally negligent products. In process management, green manufacturing emphasizes closed-loop operations involving practices like recuperation and recycling with the objective to reduce waste, capture residual value of products Ferguson and Toktay, (2006); Rogers and Tibben-Lembke, (2001), and deploy environmental technology and cleaner transportation in the downstream supply chain for pollution prevention. These two distinct components of green manufacturing are helpful

for firms to comply with environmental regulations, reducing the risk of legal fees, liability costs, and fines (Hunt and Auster, 1990). While the negligent behaviors of suppliers can devastate the green manufacturing of their downstream partners; Preuss, (2001), a systematic investigation on supplier role in green manufacturing is timely and an important environmental management topic. The green manufacturing can reduce the life cycle of product and also reduces the cost of the product. Due to environmental and ecological responsibility, companies are trying to reuse, remanufacture and recycle the used products to reduce the negative impact on environment.

## 2.2. Literature for SME's.

Taking into consideration the enterprises, the relation between development and SMEs one cannot forget that enterprises can be small or medium-sized, but they can also be large firms. Caloghirou et al. (2004) presented a work contrasting the relative impact of industry and firm specific factors on the profitability of Greek manufacturing enterprises in both SMEs and large-sized firms. The results "reveal that the impact of individual industry and firm variables on profitability are different between SMEs and large firms. The conclusion drawn from this study is that small firms base their competitive advantage on marketing rather than technology, which allows developing a differentiation strategy for these firms. As argued by many, SMEs are more flexible, speedier and adaptable than larger organizations. Constrained by size-related disadvantages, small firms typically rely on flexibility and timely responsiveness to customer needs to create and serve profitable market niches. The positive relation found in this study between the capacity to transform and profitability appears to render support to the widely held notion that quick response to market signals is vital for the survival of small firms (Caloghirou et al., 2004). Small firms might enter in the market in order to provide a fairer income distribution, among the firms operating in a certain business, to bring innovation using their knowledge either with a new idea or from the past experiences. Nowadays most of the references on the role of SMEs are considering these firms through their dynamic role.

## 3. DRIVERS AND BARRIERS IN GREEN MANUFACTURING

In green manufacturing there are a number of factors that affect its strategies. Some factors that are advantageous for the industry that have been adopted and are called success key factors or drivers while some factors can act as bottlenecks if ignored which are called barriers.

### 3.1 Success Key Factors / Drivers

From the literature it was found that there are 13 drivers that have been identified from the literature study. For manufacturing enterprises there are many motivations called

'drivers' which motivate and/or forcing the industry to adopt green manufacturing. The drivers play an active role in adoption and diffusion of green manufacturing in industry. This role of drivers is to raise awareness and convince the firms to justify investments on newer systems. Understanding of these drivers is necessary to implement green manufacturing effectively. These 13 drivers are: employee motivation, health and safety; global climatic pressure and ecological benefits; environmental concerns and legislature; green image, global marketing and competitiveness; social and environmental responsibility; organizational capabilities and awareness; government rules and legislation; scarcity of resources, higher waste generation and waste disposal problem; customer awareness, pressure and support; demand for environment friendly products; economic benefits or cost reduction benefits; society or public pressure; supplier pressure and willingness.

### 3.2. Barriers

There are some factors which act as hurdles or inhibitors or bottlenecks to the successful adoption of green manufacturing and are termed as barriers. There are a number of hindering factors that act as barriers to the implementation of green manufacturing. Proper understanding of these barriers is necessary to implement green manufacturing effectively. From the literature study it was found that 12 barriers were affecting green manufacturing practices from the survey of Indian industry. The twelve barriers are: lack of research and empirical studies; lack of customer; increment in overall cost or financial burden; lack of awareness in companies; inadequate coordination between different departments; need of development of new analytical tools and models; incompatibility with different management and manufacturing systems; lack of management commitment; lack of necessary tools; management skills and knowledge; loose government legislation; and inability to adopt adequate environmental treatment measures.

## 4. PILOT STUDY

A pilot study was conducted in manufacturing SME's which were mainly chemical based, metallurgical based and electronics based. A questionnaire was also sent to industries which were hard to sight.

## 5. RESEARCH GAP

Green manufacturing is of much importance as it will benefit the industry in long run. Having adopted green manufacturing in small and medium sized industries can make a good amount of difference. There are more number of SME's in any country than large enterprises. In developed countries the green manufacturing is either strictly implemented or not implemented at all. India is a developing country and hence green manufacturing is not much understood by many. From the literature study there

are very less journals were Indian SME's are taken into consideration. Hence very less can be known about Indian SME's. Implementing green practices for adopting green manufacturing is not healthy for a developing country's SME's like India. SME's contribute much of the country's economy but are small and medium sized and hence ignored.

## 6. CONCLUSION

Green manufacturing is a relatively a new concept about which there is more confusion and misunderstanding regarding its components, costs, benefits, and implementation. Its future game changer trends in industry, therefore, it is also uncertain. However, as customers are more awake and demand low-cost, quickly produced and designed, high-quality products characterized by extensive variety. Customers will also demand that such products be produced by processes that are environmental responsible. Whether green manufacturing is good business or a bad investment is being argued. Green manufacturing is likely to be an increasingly important issue because it is a crucial component in the international trend towards 'sustainable development'. Sustainable development has been a long term goal to meet the needs of the current generation by developing systems and processes that do not compromise the needs of future generations. Achieving this will require interdisciplinary cooperation between politicians, economists, scientists and engineers. Also implementing green manufacturing in small and medium enterprises in developing and developed countries can be assumed to be beneficial taking in account the drivers and barriers and how the organization or the firms identify them.

## 7. FUTURE SCOPE

The manufacturing industry is an extremely valuable one, but it's also one of the leading industries in energy consumption, meaning that a large portion of the planet's pollution and carbon footprint can be directly attributed to this field of work. In fact, one third of America's total energy consumption is related to the industrial sector alone, so it's not hard to gauge the overall impact that this crucial industry is having on the world at large. Implementing green manufacturing is not a new concept, but it is one that remains relatively new to the industrial sector simply because manufacturing is so reliant on highly technical equipment that requires a lot of power to run. However, if we have any hope of reducing our impact on the planet and improving the efficiency of the way we do business, then we need to look to this sector and start making some serious changes for a brighter future. With the future of the manufacturing industry heading in a greener direction, more and more businesses operating within this industry should be considering making some key changes to their processes and work patterns in order to reduce their carbon footprint and make manufacturing a greener industry.

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# Study of Relation Between Overall Equipment Efficiency and Sustainable Manufacturing for Reducing Waste during Manufacturing Process

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**Abstract:** This paper focuses on relating sustainable manufacturing (SM) to Overall equipment efficiency (OEE). It was found that implementation of OEE is typically based on the inspiration to use a basic reference measure for analyzing and comparing the utilization of resources at the plant. By relating SM to OEE, there was a reduction in wastage at the time of manufacturing from 30% to 15%. The use of OEE can also be transformed to a system for analyzing production data to identify potential areas of improvement, and supporting lean initiatives. The findings of this study are in the form of waste produced during manufacturing process. The findings can be used as an initial reference to consider OEE measures to advance the goal of manufacturing sustainability.

**Keywords:** Sustainable Manufacturing (SM), Overall Equipment Efficiency (OEE), Lean initiative

## 1. INTRODUCTION

In many industries, the effectiveness of manufacturing equipment is of the utmost importance. Overall Equipment Effectiveness (OEE) is gaining increasing interest as a key measure of considerable relevance for sustainable manufacturing. There is some research literature on OEE but it mostly deals with the technical aspects of OEE as a measure. There are very few case studies reported and when case studies are included, these typically have the role of merely illustrating a particular aspect of the measurement or definition of OEE. We identified a lack of literature concerning the implementation of OEE, i.e. how to introduce it in a plant or company, and how to use it for the continuing operations. A basic definition of OEE is:

$OEE = \text{Valuable Operating Time} / \text{Loading Time}$

Where:

- **Valuable Operating Time** is the net time during which the equipment actually produces an acceptable product;
- **Loading Time** is the actual number of hours that the equipment is expected to work in a specific period (year, month, week, or day).

To maximize equipment effectiveness it is necessary to bring the equipment to peak operating conditions and then keeping it there by eliminating or at least minimizing any factor that might diminish its performance. In other words a model for OEE calculation should be based on the identification of any losses that prevent equipment from achieving its maximum effectiveness. The OEE calculation

model is then designed to isolate losses that degrade the equipment effectiveness.

OEE measure captures the reduction of scheduled operations with respect to maintenance, production and quality effectiveness, and distinguishes between these three components. The definition of OEE is illustrated in Figure and detailed below.

$OEE = A \times P \times Q$ .

where  $A$  = Availability rate = Operating time (h) / Loading time (h)

$P$  = Performance efficiency = Theoretical cycle time (h) x Actual output (units) / Operating time (h)

$Q$  = Quality rate = [Total production (units) – Defect amount (units)] / Total production (units)



**Fig. 1. Illustration of the main components of overall equipment effectiveness (OEE).**



In addition to the losses described in the OEE metric, production units experience six common losses which reduce the productivity of an organization. By addressing

these losses, a total productive maintenance program results in increased productivity through reduction of wasteful conditions within processes.

**TABLE I: Six big losses in production**

Six Big Losses	OEE Loss Classification	Examples	Remarks
Machine Breakdowns	DTL	Fan belt breakage, tool failures, motor breakdown	Must be clearly defined so as not to confuse with small stops
Setup Loss and Minor Adjustments	DTL	Product change-over, staff shortage, material shortage	SMED is used for reducing the effects of this loss
Minor Stoppages	SL	Inspection, jams, adjustments, blocked sensing devices,	Very short stops (-5mins) not requiring technical intervention
Slow Running	SL	Poor settings and alignment	Factors that prevent the design capacity/speed from been achieved
Start-up Errors	QL	scrap and rework	Occur before the process starts in earnest
Product Defects	QL	scrap and rework	Occur during the running of the process

The following table shows the six big losses, their relation to OEE and typical examples in a production facility:  
DTL = Downtime Loss, SL = Speed Loss, QL = Quality Loss

## 2. CHALLENGES FACED IN MANUFACTURING

The Label Industry has 6 machines and across the divisions. They had specialized infrastructure for making self- adhesive Labels Made of Plastic, Paper and foil material. However the division was also involved in development of products with the customers. For such products the customer gives concept drawings known as artwork and the product is made according to the artwork.



**Fig. 2. Image showing Labels made of Plastic material**

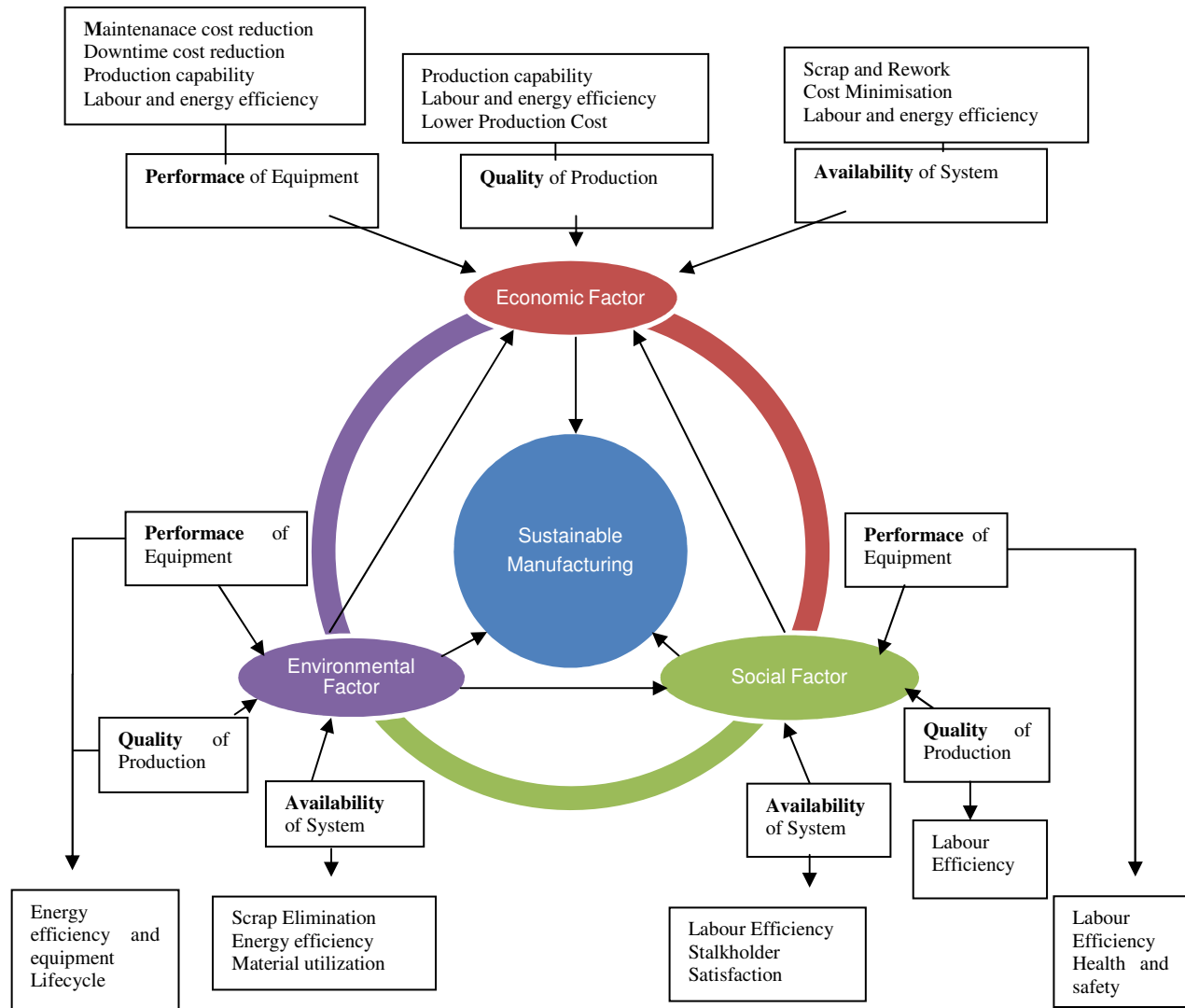
Almost all the methods and processes of manufacturing and certification were suddenly redundant. There was a multi-fold rise in the product quality and accuracies expected. Level of documentation and traceability also shot up extensively. Major challenges faced by the company are:

- The raw material in the new product was also of high standards and sourcing became a challenge.
- Waste Production was almost 30% of the raw material.
- Inexperience, lack of knowledge, limitations of available resources was causing a lot of losses at all stages of manufacturing resulting in high conversion cost. Having a unified methodology across the division was utmost important for the division to ensure growth of the division.
- Label Industry embraced Sustainable manufacturing as part of change management.

### 3. SUSTAINABILITY AND OEE.

The translation of OEE measures into manufacturing sustainability was required for greater environmental conservation, social efficiency, and economic enhancement can be seen in Fig. 3. Combination of system availability rate, equipment performance rate, and

production quality rate are the three essential factors for OEE measurement and each of these factors can be translated in all three perspectives of sustainable manufacturing. However, OEE measurement may differ amongst applications and authors as data may not be available or feasible to collect in the form required for each formula.



**Fig 3. Relating OEE measures to manufacturing sustainability**

#### 3.1. Environmental Impact

Environmental conservation is the first element considered in manufacturing sustainability. This element further benefits social efficiency, and both environment and social elements support manufacturing firms for economic enhancement. Environmental impact is the most pressing issues as manufacturing firms are confronted with demands to play an active role to reduce environmental burdens effectively and to help in achieving environmental sustainability. Rising OEE brought a better environmental

conservation through identification and elimination of major losses in manufacturing. Consequently, manufacturing is made advanced by efficient use of natural resources, consumption of energy and reduction of production rejects and waste so as to prevent harmful and irreversible effects on the environment. System availability and equipment performance were monitored and controlled to support manufacturing sustainability for better energy efficiency and prolong equipment life cycle. This was achieved by minimizing breakdown, setup and

adjustment, minor stops, and speed losses. Unpredictable and uncontrollable natures of breakdowns are typically the main source of safety and environmental hazards. By tackling breakdowns losses, manufacturing gains benefits in term of additional output, safety, environmental health, quality of end-product, customer service, competitiveness or unit costs. Through improvement of production quality, increase in OEE scores is indirectly related with energy savings, material utilisation and scrap elimination [6]. It also results in prolonged equipment life cycle that would in turn produce lesser waste, almost 15% and lesser scrap and thus keep environmental load at minimum. A smaller amount of investments for same amount production volume with less waste and scrapping of machine equipment with longer lifetime can be reached with OEE employment.

### **3.2. Social factor**

This factor is influenced by system availability, equipment performance, and production quality indirectly. Social components include labour and stakeholders. OEE encourages labour efficiency and productivity by improving visibility into operations and empowering operators. This includes instantaneous identification of the actual causes that adversely impact production, whether through human input (process / labour issues) or equipment / material issues. The net effect of reduction in machine downtime, escalation productivity of labours, and minimisation of defects is the ability to achieve higher production levels with the same amount of resources. Besides, high OEE performance can reduce incidents and accidents (safety issue) and other health hazard issues and encouraging a healthy work culture [7]. Labour efficiency is also further reflected in the joint effects of many influences, including capacity utilisation, energy efficiency, and materials utilisation, the organization of production, and managerial skill. Moreover, managing OEE also can support the enterprises to enhance their competitive position and create additional shareholders value and satisfaction. From this, manufacturing firms also can provide equitable opportunities, encourage diversity, promote connectedness within and outside the community, ensure the quality of life and accountable governance structures for social sustainability.

### **3.3. Economic factor**

Economic performance can be realised in sustainable manufacturing operation through promoting asset management discipline and comprehensive measurement systems. This can assist in identifying asset performance and its consequential impacts on profitability and competitiveness by OEE [8]. Additionally, OEE also can provide solution in its entirety for the process industry with an objective to reduce the overall costs, bringing in a change and savings in resources through and return on assets and maintenance investment. Greater machine availability results in more products, more income and thus

higher value and lower maintenance costs produce higher value by avoiding expenditure. This includes allocation repair labourers from an existing group of resources instead of hiring someone on an emergency basis. Thus can result in huge savings compared to repairing a machine after the breakdown has happened. OEE identifies lost production and the hidden potential in a machine or a cell that can deliver additional throughput and increase production capability [9]. Cost savings through production consistency improvement and waste minimization also contribute for economic vitality. Reduction of scrap and rejects directly improve production quality. Hence it leads to a better energy efficiency, labour efficiency and lower product costs, besides higher customer satisfaction. OEE plays an important role in sustaining firms' competitive advantage because moderate changes in OEE can result in significant changes in return on investment since it reduces the production cost per product volume, yielding a higher profit margin and/or providing more flexibility in potential price wars. The decision making of OEE is undertaken at all levels to achieve elimination of material, energy consumptions and waste production, while taking advantage of cost benefits leading to manufacturing sustainability development [10]. These imply less environmental pollution on account of system longevity and optimum utilization of material and energy for the limited resources scenario that governs the development of future systems.

## **4. CONCLUSION**

The study indicates that the OEE measure can be related into manufacturing sustainability. Any improvement made in the OEE factor (system availability, equipment performance, and production quality) will have an indirect and positive impact on environmental conservation, social efficiency, and economic vitality of the manufacturing firms. The manufacturing sustainability objectives to increase the productivity, besides elimination of consumed resources without compromising product or service quality, competitiveness and profitability can be realised with the support of employing OEE in the firms. This study provides an insight for manufacturers on how OEE influences manufacturing sustainability and waste material during production was reduced to 15%. Future studies might improve this conceptual model by adding other factors and losses that are not considered in OEE measurement such as planned maintenance, shortage of raw materials, unavailability of labour, etc. These additional essentials may cover the whole issues in manufacturing firms therefore expand the effect of OEE on manufacturing sustainability in particular.

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# Six Sigma Approach for Sustainability in Manufacturing Industries: A Review

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**Abstract:** In current scenario, customers are becoming aware about the environment and they are asking for the manufacturing organizations for greener products. Stakeholders have made environmental and social performance as the prior consideration with the economic performance of the company. Transformation of becoming environmentally and socially sustainable is challenging for the companies. Implementation of sustainability is only can be attained successful with the proper tools and management. Six Sigma has proven as a very systematic set of tools and technique to solve the problems in industries. In developing countries like India, it is very important for manufacturing industries to achieve the sustainability of their improvement and hence it is very much important to utilize one of the paradigms which can provide synergistic integration with sustainability. This can be achieved by Six Sigma being an effective methodology in developing a road map for the company to achieve the sustainability. Here in this paper, the study of the literature of sustainability through six sigma is explained in manufacturing industries.

**Keywords:** Six sigma, Sustainability, manufacturing industry

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## 1. INTRODUCTION

In Today's globally competitive market, stakeholders are pressuring industries to improve social and environmental performance, organizations have now been forced to change their approaches to managing processes and operations. Sustainability has turned out to be as a major concern for organizations to integrate economic, social and environmental issues in their business. In current scenario, customers are becoming aware about the environment and they are asking for the manufacturing organizations for greener products. Stakeholders have made environmental and social performance as the prior consideration with the economic performance of the company. Transformation of becoming environmentally and socially sustainable is challenging for the companies. To meet the quality requirement of the customer different Quality management systems/tools/ techniques such as total quality management, lean management, continuous improvement and Six Sigma has evolved over the period of time. Six Sigma is a quality management initiative that takes the methodological approach based on data attempting to eliminate the defects to minimize standard deviation to desired level of quality (Six Sigma, 2010). Here in this paper, the study of the literatures of sustainability through six sigma is explained in manufacturing industries.

## 2. SUSTAINABILITY/SUSTAINABLE DEVELOPMENT

The concept of sustainability investigates the relationship between financial improvement, environmental quality, and social quality. This idea has been advancing since 1972,

when the international community initiated the connection between quality of life and environmental quality in the Conference of United Nations on the Health Environment in Stockholm. In any case, until 1987 it was not available that the expression "sustainable development" had been characterized as "development that can meet the needs of the present generation without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). The another similar definition of balancing the people, profit and planet had been given by the Environmental Protection Agency (2003): "Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations." This definition built up the requirement for coordinated basic leadership that is equipped for adjusting individuals' financial and social needs with regenerative limitation of the natural environment. Sustainability is a procedure of progress in which the misuse of assets, the introduction of technological development, and institutional change are made consistent with future as well as present needs.

As per National Council for Advanced Manufacturing (2010), for a manufacturing organization sustainability is expected to create the manufactured products which are utilizing the full potential of procedures with maximum benefits, without any negative impact on environment, conserving the resources from nature and energy and safe for employee, consumer and society. Zhou et al. (2000) suggested that with all the limited resources production of the product should also meet the requirement of the

population. Consequently, for the accomplishment of sustainability in manufacturing organization Faulkner and Badurdeen (2014) considered not just the item and procedures required in its creation but the whole production network and the assembling framework of the production. Qui et al. (2013) stated that over the period of time sustainability was the part of different systems which were concerning environmental management, health and safety management as well as social responsibility management. Because of this reason, numerous policies and rules had been issued by different organizations in addition, organizations keeping in mind the end goal to help organizations execute an appropriate corporate social responsibility.

### 3. DIFFERENT APPROACHES OF SUSTAINABILITY

Sustainability can be observed as a standard vision or policy i.e., outlining, creating and executing all the strategy explanations for the accomplishment of sustainability (Bonn and Fisher, 2008). On the off chance that an organization is accomplishing what it gone for, for example, higher benefits, higher consumer satisfaction, minimum or zero defects/ rejection, cost reduction, separated products and services, full potential used manufacturing processes and high level of quality; at that point the industry should be in an effective sustainable state (Bonn and Fisher, 2008). Onwueme and Borsari (2007) see the issue of sustainability as a worldwide and expresses that each organization and individual has a "sustainability deficiency" and in this way there is dependably an opportunity to get better. An organization can accomplish sustainability if and only if its workers and higher administration know about requirement of sustainability and the organization objectives those would empower it to accomplish the coveted "sustainability" (Onwueme and Borsari, 2007). Montgomery (2010) presents a modern framework for the achievement of enterprise excellence and sustainability. These tools and techniques incorporate Six Sigma (DMAIC), Design for Six Sigma and lean (Montgomery, 2010). Through these three paradigms organization is about to excellence in all areas of the business where the process is going on.

As indicated by Thamapillai (2010), the condition of sustainability of an industry is driven by the surrounding environment or market in which the organization works. At the point when an organization works in a competitive surrounding environment, the majority of the operational and key activities of the organization is driven by its competitors. This reliance on competitor strengths is because of the examination that an organizational behavior to audit its service and processes with that of different organizations in the market and subsequently makes progress toward sustainability. An alternate idea of sustainability is identified by Stuteville and Ikerd (2009), states that sustainability can be achieved process

improvement and removing the errors and continuing the error less status. Stuteville&Ikerd, (2009) have found that for any organization to be continued of existence in future has to rely on the improving of the services & products and ability to follow the policies of sustainable improvement processes.

Blus, (2008) revealed that the operating cost of the company and market position strength increase with the implementation of sustainable strategies

### 4. LIMITATION OF THE SUSTAINABILITY APPROACH

As per Nunes and Bennett (2010), it is very important for the organizations go green, there is unavailability of a clear path to make the decisions when a company is going for sustainability. So for going green for any organization, it is limited to take decisions in facilities, logistics, product and process design, etc. All these decisions are to be taken through a systematic approach which is a limitation of the green. Green is not able to meet the corporate goals such as profitability and requirements. The reason behind that in some cases green activity not able to give profit, which are related to corporate goals. Green has operational limitation also, for example, it will cost to an organization which is going to start using a new solar panels as is costly to buy and install. The installation of energy saving equipment is not always returning the capital cost. In sustainability, the main limitations are to take the decision of investment on priority basis with satisfying the corporate goals and profitability. The other limitation of green production is lack of practices and tools, able to collect and use statistical data to control and monitor processes and disclose the remaining problems after the elimination of waste. Systematic methodology of Six Sigma can be effectively used with integration of green or clean production to overcome the barriers of green manufacturing which leads to Sustainable Six Sigma (Anass et al., 2016).

### 5. SIX SIGMA

In the simple meaning of 'Six Sigma' in mathematics which indicates Six Standard Deviations (plus or minus) from the arithmetic mean. As a program, it presents a "structured and systematic approach" to process improvement. (Harry and Schroeder, 2000; Henderson and Evans, 2000). One of the simplified definition of six sigma is a project based approach for solving specific problems of industry, Hammer (2002). Linderman et al. (2003) accentuated the requirement for a typical meaning of Six Sigma and characterized it as 'A sorted out and precise strategy for specific process improvement and new product and service improvement that depends on statistical and scientific techniques to make sensational reductions in customer defined defects of products. But over the years of implementation of six sigma, it has been changed from its

statistical definition towards the change management approach in the organization.

Some authors have defined Six Sigma as a target to manage the variation of the process, performance indicators which are most important and never ending continuous improvement in process. Six Sigma is a methodology offering a systematic problem solving techniques through its structured approach. It is defined as the management system that helps in executing a leadership, drive, step by step methodology to follow across the organization. However, Schroeder et al. (2008), have found out that huge numbers of the meanings of Six Sigma found in the writing are exceptionally broad and don't give components — or elements (factors, develops, ideas) and characterized "Six Sigma as a composed, parallel-meso structure to decrease a variety of hierarchical procedures by utilizing change authorities, an organized strategy and execution measurements with the point of accomplishing key destinations". As indicated by Zhang et al. (2011), it is almost difficult to create formal calculated meaning of Six Sigma since it is driven by the changing needs of the industries and consultants needs to constantly offer something new and particular. It is apparent from the way that, "Six Sigma continues to draw tools and concepts such as Kano Analysis from marketing research, change management from Organization Behavior, Supply Chain Optimization from operations research and Hosin Planning from Toyota". Six Sigma is a taught, systematic data collection based approach and procedure for taking out defects in any procedure – from manufacturing to transactional and from product to service.

Six Sigma methodology contains the proven scientific and systematic methodology with statistical tools and techniques for making the process better. Nakhai & Neves (2009) have considered the Six Sigma important strategy for excellent operation and business improvement. Early started by Motorola in 1980s, six sigma as a systematic approach to reduce defects with improvement in quality by reducing the variation of the process. Accordingly, to Mortimer (2006) six sigma is used for the reduction of the variation of the process, identification of defect causes, elimination of causes from its root to improve the quality and get the profit in. Six sigma tools and technique is a systematic approach to solve the problems through Define, Measure, Analyze, Improve and Control called as DMAIC. The philosophy utilizes an advanced process, investigation, information gathering, quality administration and control and measurable strategies in a structure (Soti et al., 2010). This approach requires a procedure to deliver 99.99966% of the items or the administrative units to be sans imperfection which implies that there must be only 3.4 defective units for every million (Aboelmaged, 2010; McCarty and Fisher, 2007). It can be said that if all procedures of business produce 99.99966% quality products or services, it will increase the customer satisfaction, increase in profit,

increase in the business, best return from the investment and a differentiated market share advantage over the competitive market.

## 6. SIX SIGMA INTEGRATION WITH SUSTAINABILITY IN MANUFACTURING INDUSTRIES

Different organizations have embraced Six Sigma for assortment of purposes be that as it may, the center objective was to accomplish economic sustainability through business excellence and good flow of work (Poudlove, Moxham and Boaden, 2008). For the economic related achievement, the quality improvement is most required from all its areas (Mahadevan, 2010). Example of General motors which reduced the cost of the transportation by \$ 12 million by using Kanban, as a part of the implementation of Six Sigma. According to Giardina (2006) 39% of the cost saved by the Robins Air Force Base in C-130 paint shop by reducing unnecessary tools, material and equipment and saved up to \$ 3738 hundreds in operating savings. Also improved in the worker safety to increase in production and also reduced the usage of chemical from 9 to 3.3M was listed in the list of organizations to start the implementation of Six Sigma. 3M also implemented Lean Six Sigma and to accomplish the environmental sustainability as a part of the three pillars of sustainability. The organization is pioneer being used of lean Six Sigma tools and techniques to improve the process and quality. In an initial stage of implementation of Six Sigma with a specific end goal to achieve the operational sustainability the organization trained more than hundred thousand workers. 3M got good results after implementing some of the results are Increase in the energy efficiency 7% and reduced the waste and net sales increase was 5% from early period of time. All these achievements were the outcome of the efforts for environmental and operational sustainability. Up to 2005, implemented six sigma in industry and by reducing environmental pollution, improving to standard workflow, redesigning of tools and equipment, process improvement and product development saved money up to \$1 billion (3M Lean Six-Sigma and Sustainability, 2010).

Byrne (2007) likewise declares about organization actualize Six Sigma to actualize the development. The initial years of implementation of Lean Six Sigma many organization like Caterpillar got good outcomes. In 2004, after the first decade of the implementation of the Lean Six Sigma, Caterpillar was meant to build the income of \$ 10 billion through Lean Six Sigma. Caterpillar was centered towards accomplishing economic stability. The organization's top management highlighted that six sigma had contributed very important part in the sales profit of their product. Six Sigma is additionally building the culture of constant progress in the organization and increase in business with picking up productivity in all regards. General electric spared \$8 billion in the wake of actualizing Six Sigma in three years and According to Leahy (2000), that six sigma

implementation has saved about \$1 billion in Wall- Mart. In one of the case study of dairy producer, authors highlight the key success criteria that play an important part in an effective deployment of lean six sigma in the food processing industry. It is illustrated with a number of countermeasures that could be relevant to other food-processing companies, such as the importance of relevant KPIs, and the potential of SPC when eliminating wasted raw materials and energy usage to contribute to a more environmentally sustainable supply chain (Powell et al., 2017).

Seifedine K. (2013) has successfully implemented six sigma methodology for environmental sustainability in the oxygen plant, where DMAIC approach was used and sigma level improved from 1.35 sigma to 2.61 sigma for reduction in excess oxygen. Further author found that methodology of Six Sigma contains set of tools and techniques that can be used by the team after giving training increases the problem solving rate. A frame work proposed by the Zhang & Awasti (2014) integrates Sustainable manufacturing and Six Sigma. Also the frame work is given with details steps of problem definition to getting the sustainable development and maintaining the same after achievement.

## 7. CRITICAL SUCCESS FACTORS OF SIX SIGMA AND SUSTAINABILITY

Different authors have identified different factors for the successful implementation of the Six Sigma with Sustainability. EPA (2009) and Zhang (2014) have given that the human resource department is success factor for the implementation. Top management involvement and support to the employee is also one of the most important factor identified by the authors Bergmiller and McCright (2009a), Maskell and Pojasek (2008), Pampanelli et al. (2014). In most of the industries, communication and people involvement have also played an important role in successful implementation of six sigma for sustainability. Longoni and Cagliano (2011), Alsagheer and Hamdan (2011), Alves and Alves (2015). Calia et al. (2009), Wong and Wong (2014) have identified that teamwork, training and education are also an important factor to be considered for the success. Six Sigma uses the set of tools and techniques which are from statistics and improves the process performance by reducing the variation. Some of the authors uses the measurement system analysis tool as the proper measurement is also found out as the one of the most critical success factors for the implementation.

## 8. CONCLUSION

The aim of this study was to define the sustainability, highlight hurdles to sustainability and demonstrate possible integration of Six Sigma to overcome the hurdles of sustainability. In this literature review different case study of implementation in manufacturing industries has been

reviewed and the successful integration of the Six Sigma and Sustainable development i.e. Sustainability is carried out for factors such as social, economic and environmental. Various studies carried out till now in the domain of Six Sigma is clearly indicating that very few attempts have been made to utilize the strength of Six Sigma with context to environment domain which demanding the initiation of possible collaboration of two paradigm which can produce synergic results in terms of the business improvements and environment protection.

It was also observed from the literature review that evidence of studies in terms of the sustainability is mostly carried out in the developed countries and very few evidence the developing countries like India. In developing countries such as India, Industries are less worried about environmental protection. For the large manufacturing industries six sigma is only for the improvement of quality by reducing the defects and achieving the financial benefits through implementation of tools and techniques of six sigma but over the period of time six sigma is effectively able to implement sustainability i.e. environmental, social and financial benefits to the industry. The integrated focus of sustainability and Six Sigma for an industry is ultimately converted into monetary benefits for the industry.

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# Biofuel Production - A Sustainable Manufacturing

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**Abstract:** Global population is increasing day by day, which, in a way is leading to the utilization of natural resources and fuels. This phenomenon is gradually paving a way towards the depletion of these resources. One of such important necessity to human kind which is in the verge of depletion is the fossil fuel. Since it cannot be replenished, once it gets depleted, it cannot be produced again. Declining global oil producing capacity combined with a rising oil demand provides the most compelling global reason for alternative fuels. Present review focuses on the production of such fuels which are not only potential alternatives for fossil fuels, but also are eco-friendly in nature, which are called Biofuels. In this article, production of biofuel from plants & algae; advantages & disadvantages; and their role in effective replacement of existing fuels are mainly discussed.

**Keywords:** Biofuel, fossil fuel, algal oil, green diesel.

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## 1. INTRODUCTION

As today's technology progresses, the natural environment suffers from the detrimental effects of pollution. Pollution of different environments is due to human activities in recent years. Today's highly industrialized environment is charged with a multitude of potentially toxic chemicals. Environmental pollution caused by the release of a wide range of compounds as a consequence of industrial progress has now assumed serious proportions. The increase in industrial activities has intensified environmental pollution and the deterioration of some ecosystems, with the accumulation of pollutants. This pollution and excessive exploitation of the natural resources such as fossil fuels, is gradually leading to the depletion of the reserves. Even though petroleum products are the major source of energy for industry as well as day today life, it also poses major concern over hydrocarbon release during its production. These are released into soil, air and water which poses a great danger to the natural habitats. Sulphur emission through fossil fuel combustion is a major cause of acid rain and air pollution. Apart from hydrocarbon release, the release of heavy metals into the environment has become a major issue. As a remedy for all these problems, biological factors are coming into picture rather than using chemical substitutes which result in additional pollution. Methods like biosorption, biofuels production, bioremediation, phytoremediation and biodegradation are carried out in order to subside or decrease the effects of these pollutants in the environment. Micro organisms play an important role in this process. Microorganisms are known for their ability to metabolize a variety of chemical compounds including aliphatic and aromatic hydrocarbon, fatty acids and other environmental pollutants.

World crude oil production is about 86 million barrels/day and estimated to reach 118 million barrels/day until 2030. With depletion of conventional petroleum reserves and increase of hydrocarbon fuel demand, there is no doubt that there will be a tremendous demand on the development of heavy oil reservoirs in the coming decades. Rising oil prices and uncertainty over the security of existing fossil fuel reserves, combined with concerns over global climate change, have created the need for new transportation fuels and bio products to substitute for fossil carbon-based materials. Microbial enhanced oil recovery (MEOR) processes, Thermal enhanced oil recovery and gas injection are also being employed for efficient recovery of oil. The search for a clean and cheaper fuel has become the need of hour. Taking the waste product of one process and using it as input or fuel for another process is one way to accomplish this; it makes intelligent use of resources, decreases pollution, and broadens their application in sustainable approach. With depletion of conventional petroleum reserves and increase of hydrocarbon fuel demand, there is no doubt that there will be a tremendous demand on the development of heavy oil reservoirs in the coming decades. Biotechnology has the potential to produce bulk compounds from renewable materials with reduced greenhouse gas emission. It has been suggested that large scale biofuel production, especially in combination with sequestration forestry, can achieve a low cost reduction in greenhouse gas levels, in particular CO₂, and hence lead to meeting the ultimate objective of the Kyoto Protocol to the UN framework convention on climate change (UNFCCC). Biofuel (the fuel derived from biological materials) substitutes fossil fuels and thus, through fossil fuels not extracted, prevents release of underground fossil carbon. Biofuel is also a renewable fuel that provides chemically

stored energy that can potentially substitute fossil fuel with minimal infrastructural change and may provide a backstop technology until other innovative technologies take a sufficient market role. Microbes are wonderful organisms which contribute more to the environment by playing vital role in various processes. They are important organisms from industrial point of view of which bacteria are most important.



**Fig. 1. Sources of Biofuel**

## 2. BIOFUEL GENERATIONS

### *First-generation biofuels*

"First-generation" or conventional biofuels are biofuels made from food crops grown on arable land. With this biofuel production generation, food crops are thus explicitly grown for fuel production, and not anything else. The sugar, starch, or vegetable oil obtained from the crops is converted into biodiesel or ethanol, using transesterification, or yeast fermentation.

### *Second-generation biofuels*

Second generation biofuels are fuels manufactured from various types of biomass. Biomass is a wide-ranging term meaning any source of organic carbon that is renewed rapidly as part of the carbon cycle. Biomass is derived from plant materials, but can also include animal materials. Whereas first generation biofuels are made from the sugars and vegetable oils found in arable crops, second generation biofuels are made from lignocellulosic biomass or woody crops, agricultural residues or waste plant material (from food crops)

This has both advantages and disadvantages. The advantage is that, unlike with regular food crops, no arable land is used solely for the production of fuel. The disadvantage is that unlike with regular food crops, it may be rather difficult to extract the fuel. For instance, a series of physical and chemical treatments might be required to convert

lignocellulosic biomass to liquid fuels suitable for transportation.

### *Third-generation biofuels*

From 1978 to 1996, the US NREL experimented with using algae as a biofuels source in the "Aquatic Species Program".^[10] A self-published article by Michael Briggs, at the UNH Biofuels Group, offers estimates for the realistic replacement of all vehicular fuel with biofuels by using algae that have a natural oil content greater than 50%, which Briggs suggests can be grown on algae ponds at wastewater treatment plants.^[11] This oil-rich algae can then be extracted from the system and processed into biofuels, with the dried remainder further reprocessed to create ethanol. The production of algae to harvest oil for biofuels has not yet been undertaken on a commercial scale, but feasibility studies have been conducted to arrive at the above yield estimate. In addition to its projected high yield, algaculture — unlike crop-based biofuels — does not entail a decrease in food production, since it requires neither farmland nor fresh water. Many companies are pursuing algae bioreactors for various purposes, including scaling up biofuels production to commercial levels.^{[12][13]} Prof. Rodrigo E. Teixeira from the University of Alabama in Huntsville demonstrated the extraction of biofuels lipids from wet algae using a simple and economical reaction in ionic liquids.

### *Fourth-generation biofuels*

Similarly to third-generation biofuels, fourth-generation biofuels are made using non-arable land. However, unlike third-generation biofuels, they do not require the destruction of biomass. This class of biofuels includes electrofuels, and photobiological solar fuels. These fuels are carbon-neutral. The conversion of crude oil from the plant seeds into useful fuels is called transesterification. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

In 2010, worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009, and biofuels provided 2.7% of the world's fuels for road transport. Global ethanol fuel production reached 86 billion liters (23 billion gallons US) in 2010, with the United States and Brazil as the world's top producers, accounting together for about 90% of global production. The world's largest biodiesel producer is the European Union, accounting for 53% of all biodiesel production in 2010. As of 2011, mandates for blending biofuels exist in 31 countries at the national level and in 29 states or provinces. The International Energy Agency has a goal for biofuels to meet more than a quarter of world demand for transportation

fuels by 2050 to reduce dependence on petroleum and coal. The production of biofuels also led into a flourishing automotive industry, where by 2010, 79% of all cars produced in Brazil were made with a hybrid fuel system of bioethanol and gasoline.

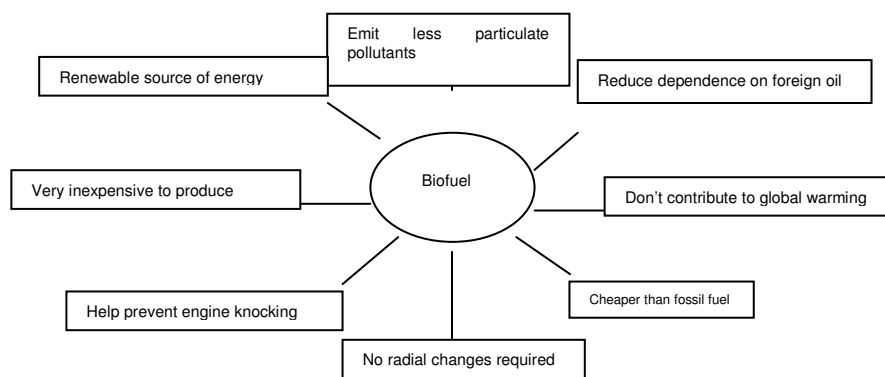
There are various social, economic, environmental and technical issues relating to biofuels production and use, which have been debated in the popular media and scientific journals. These include: the effect of moderating oil prices, the "food vs fuel" debate, poverty reduction potential, carbon emissions levels, sustainable biofuel production, deforestation and soil erosion, loss of biodiversity, impact on water resources, rural social exclusion and injustice, shantytown migration, rural

unskilled unemployment, and nitrogen dioxide (NO₂) emissions.

### 3. ADVANTATGES AND DISADVANTAGES

#### *Advantages:*

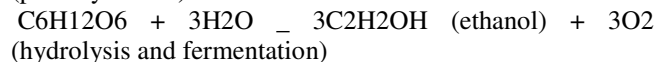
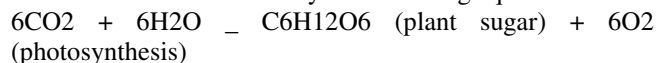
The main advantage of biofuels is that, they are considered 'carbon neutral' by some people. This is because the carbon dioxide they release when burnt is equal to the amount that the plants absorbed out of the atmosphere. Therefore, they don't contribute to global warming. However, it does require some fuel to power the machinery on the farms where biofuels are produced. Still, they are better than fossil fuels! Research suggests that they reduce carbon emissions by 50-60%.



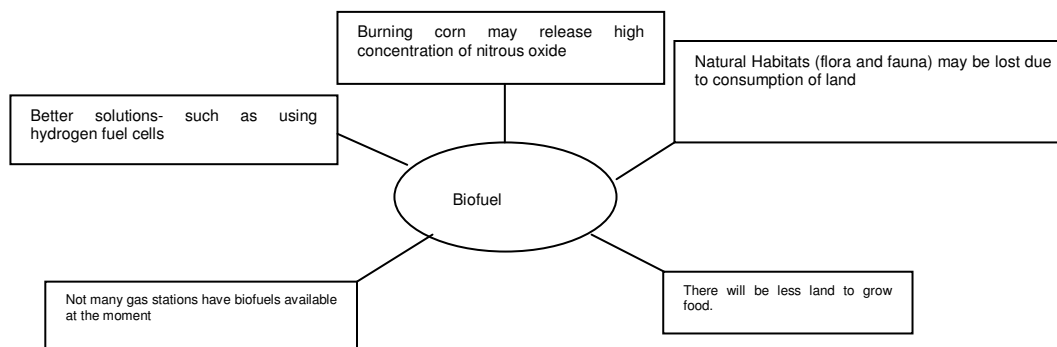
**Fig. 2. Advantages of Biofuel**

#### *Reduction in greenhouse gas emissions*

The net CO₂ emission of burning a biofuel like ethanol is zero since the CO₂ emitted on combustion is equal to that absorbed from the atmosphere by photosynthesis during the growth of the plant (sugarcane) used to manufacture ethanol. This is illustrated by the following equations:



Life cycle analysis, from well to wheels, shows that ethanol has the lowest CO₂ emission among the major transportation fuels. Biofuels contribute significantly to climate change mitigation by reducing CO₂ emissions. Biodiesel projects can qualify as CDM projects and thus bring in additional income through the sale of certified emission reductions.



**Fig. 3. Disadvantages of Biofuel**

### ***Disadvantages:***

The main disadvantage of biofuels is that, setting aside land to grow biofuels means that there is less land to grow food. Some people contend that this will lead to more people around the world starving as there will simply not be enough food to feed everyone. It is also possible that food prices will rise as a result. Agricultural crops most commonly used at present for biofuel production and climate protection can readily lead to enhanced greenhouse warming by N₂O emissions. The main disadvantage of biofuels is that, setting aside land to grow biofuels means that there is less land to grow food. Some people contend that this will lead to more people around the world starving as there will simply not be enough food to feed everyone. It is also possible that food prices will rise as a result.

### ***Direct cellulose fermentation as biofuel source:***

Cellulose is the most abundant biopolymer in the world. Cellulose constitutes the highest proportion of municipal wastes; it represents a major source of renewable energy and raw materials. Therefore, the utilization of cellulosic wastes to produce energy is potentially of great importance. Discarded cellulosic biomass derived from forestry, agriculture and municipal sources are potential feedstocks for the synthesis of biofuels (and other value-added bioproducts) that could displace fossil fuel consumption and reduce greenhouse gas emissions. The crystalline structure of cellulose however makes it difficult to hydrolyze. Conventional production of ethanol or H₂ from cellulose via fermentation involves a complex process of pre-treatment including:

- (i) Cellulase production,
- (ii) Hydrolysis of cellulose and hemicelluloses (if present), followed by
- (iii) Fermentation of hexose sugars generated by cellulose hydrolysis and pentose sugars generated by hemicelluloses hydrolysis (if present).

Current strategies to produce fuel ethanol from cellulose, referred to as “second-generation” biofuels, utilize simultaneous saccharification and fermentation (SSF) or simultaneous saccharification and co-fermentation (SSCF). Consolidated bioprocessing (CBP) is an alternative processing strategy in which cellulase production, substrate hydrolysis and fermentation are accomplished in a single process step by microorganisms that express cellulolytic (and hemicellulolytic) enzymes. CBP offers the potential for lower biofuel production costs due to simpler feedstock processing, lower energy inputs (and therefore better energy balance) and higher conversion efficiencies than SSF based processes. CBP is an economically attractive near-term goal for process for “third generation” biofuel production.

### ***Production of biofuels from algae:***

Algae are the fastest-growing plants and the most widely distributed organisms in Nature. Microalgae are veritable miniature biochemical factories and appear more photosynthetically efficient than terrestrial plants and are efficient CO₂ fixers. The ability of algae to fix CO₂ has been proposed as a method of removing CO₂ from flue gases from power plants, and thus can be used to reduce emission of greenhouse gases. The dry cell weight contains about 50% oil. Algae are a large group of photoautotrophic, mixotrophic and heterotrophic lower plants. Algae can be typically subdivided into two major categories, based on their relative sizes: macroalgae and microalgae. Microalgae are capable of producing 30 times the amount of oil per unit area of land, compared to oilseed crops. It is the first largest biomass resource.

Microalgae are abundant in diverse ecological aquatic habitats such as fresh, brackish, marine, and hypersaline water environments within a wide range of temperatures, pH values and salinity. Production of bioethanol from algal biomass is being harnessed extensively due to its suitable utilization on a commercial scale. Theoretically, microalgae could grow in different kind of water, nutrients and land saving sites for oil production. Even better production can be achieved in the desert, where the sunlight is stronger. As the focus on algae as the fuel of the future increases, the need to make algae biofuel more sustainable falls into a handful of categories from economic assessment to engineering.

### ***Advantages of algae***

- Algae can be grown using land and water unsuitable for plant or food production, unlike some other first- and second-generation biofuel feedstocks.
- Select species of algae produce bio-oils through the natural process of photosynthesis requiring only sunlight, water and carbon dioxide.
- Growing algae consume carbon dioxide; this provides greenhouse gas mitigation benefits.
- Bio-oil produced by photosynthetic algae and the resultant biofuel will have molecular structures that are similar to the petroleum and refined products we use today, than 2000 gallons of fuel per acre per year of production. Approximate yields for other fuel sources are far lower:
  - Palm — 650 gallons per acre per year
  - Sugar cane — 450 gallons per acre per year
  - Corn — 250 gallons per acre per year
  - Soy — 50 gallons per acre per year
- Algae used to produce biofuels are highly productive. As a result, large quantities of algae can be grown quickly, and the process of testing different strains of

algae for their fuel-making potential can proceed more rapidly than for other crops with longer life cycles.

- If successful, bio-oils from photosynthetic algae could be used to manufacture a full range of fuels including gasoline, diesel fuel and jet fuel that meet the same specifications as today's products.

#### Disadvantages to algae oil production

- Produces unstable biodiesel with many polyunsaturates.
- Relatively new technology.
- Biodiesel performs poorly compared to its mainstream alternative. Algae have the potential to yield greater volumes of biofuel per acre of production than other biofuel sources. Algae could yield more. Research into algae for the mass-production of oil is mainly focused on microalgae; organisms capable of photosynthesis that are less than 0.4 mm in diameter, including the diatoms and cyanobacteria; as opposed to macroalgae, such as seaweed. The preference towards microalgae is due largely to its less complex structure, fast growth rate, and high oil content (for some species). However, some research is being done into using seaweeds for biofuels, probably due to the high availability of this resource.

The following species listed are currently being studied for their suitability as a mass-oil producing crop, across various locations worldwide:

- *Botryococcus braunii*
- *Chlorella*
- *Dunaliella tertiolecta*
- *Gracilaria*
- *Pleurochrysis carterae*

#### Other method of Biofuel generation:-

Scientists have employed many other methods by which biofuels can be produced. For example, Biodiesel production was achieved by blending of poultry manure (PM), paper pulp and algae waste sludge in co-digestion producing biomethane, digestate, which is again filtrated to get semi-solid and aqueous, the former as biofertilizer and latter was used in algal cultivation to enhance algal biomass for biodiesel production. Dimethyl/diethyl carbonate can be adopted as an extraction solvent and Trans-esterification reagent at the same time for in situ lipase-catalyzed reactive extraction of oilseeds for biodiesel production.

Palm oil like other vegetable oils can be used to create biodiesel, as either a simply processed palm oil mixed with petrodiesel, or processed through Transesterification to create a palm oil methyl ester blend, which meets the International EN 14214 specification. From 2007, all diesel sold in Malaysia must contain 5% palm oil. Malaysia is emerging as one of the leading biofuel producers, with 91 palm oil plants approved and a handful now in operation. The global production of Palm Kernel Cake (PKC), a by-product of oil extraction from the nut of the palm tree,

*Elaeis guineensis*, is ever increasing due to the tremendous growth of the oil palm industry in many parts of Asia and Africa (PORLA, 2000).

Niger seed oil cake (*Guizotia abyssinica*) is cultivated in tropical countries and is quite expensive as it is imported usually from Ethiopia and India. Niger seed oil has been identified as a potential biodiesel crop because of the presence of 50–60% the oil called biocrude, which can be converted into biodiesel by chemical or lipase mediated esterification.

Corn steep liquor (by-product of the corn milling industry) is a low-cost nutritional medium used successfully in the production of ethanol by *Zymomonas mobilis*, succinic acid by *Anaerobiospirillum succiniciproducens* and arabinanase by *Fusarium mycelium*.

#### 4. CONCLUSION

Biofuel generation is need of hour, The volatility of oil prices poses great risks for the world's economic and political stability, with unusually dramatic effects on energy-importing developing nations. Renewable energy, including biofuels, can help diversify energy supply and increase energy security.

Biofuels can be produced by various means which include lignocellulosic wastes, plants, algae, starch, vegetable oils, etc. Algae are considered as Third generation biofuels due to their novel properties and important advantages like, they can be grown on the land and water which may be unsuitable for the growth of plants; they produce biofuel by utilizing natural resources such as sunlight, water, and CO₂, etc. They are even comfortable to grow and maintain. Thus, taking into account of the above mentioned points, a conclusion can be drawn that algal fuel would be the superior alternative for the fossil fuels.

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# Green Building Concept for Smart City using Green Rating for Integrated Habitat Assessment (GRIHA)

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**Abstract:** A green building, which is also known as a sustainable building is designed to meet some objectives such as occupant health; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment. It is an opportunity to use the resources efficiently while creating healthier buildings that improve human health, build a better environment, and provide cost savings. All the development projects lead to over-consumption of natural resources. There are several tools which evaluate the efficiency of the buildings like GRIHA, Leadership in Energy and Environmental Design (LEED), etc. GRIHA is an Indian green building rating system, which developed under the climatic conditions of India. GRIHA rating system covers all the major socio economic aspect. GRIHA tool helps to evaluate the energy consumption of the building and its possible intervention to save the energy.

**Keywords:** Green building, smart city, GRIHA

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## 1. INTRODUCTION

Due to continuing migration of people from rural area to urban area and urbanized area there are many problems faced by the urban area. So there is difficulty to provide better living condition to each and every citizen. Overcome of that condition we construct smart city, sustainable city as the solution of urbanization as well as construct green building for the good living condition of human health. Words like “sustainable” and “green” have long been associated with premium buildings. Today, these words have become part of global conversation about everything from a worldwide movement towards energy efficient, environmentally sound buildings to enterprise-wide real estate portfolios.

The construction sector poses a major challenge to the environment. Globally, buildings are responsible for at least 40% of energy use. An estimated 42% of the global water consumption and 50% of the global consumption of raw materials is consumed by buildings when taking into account the manufacture, construction, and operational period of buildings. In addition, building activities contribute an estimated 50% of the world's air pollution, 42% of its greenhouse gases, 50% of all water pollution, 48% of all solid wastes and 50% of all CFCs (chlorofluorocarbons) to the environment. India too faces the environmental challenges of the construction sector.

Resource-intensive materials provide structure to a building and landscaping adds beauty to it, in turn using up water and pesticides to maintain it. Buildings are thus one of the major pollutants that affect urban air quality and contribute to climate change. Hence, the need to design a green

building, the essence of which is to address all these issues in an integrated and scientific manner. The aim of a green building design is to minimize the demand on non-renewable resources, maximize the utilization efficiency of these resources when in use, and maximize the reuse, recycling, and utilization of renewable resources. It is evolved through a design process that requires input from all concerned – the architect; landscape designer; and the air conditioning, electrical, plumbing, and energy consultants – to work as a team to address all aspects of building and system planning, designing, construction, and operation. They critically evaluate the impacts of each design decision and arrive at viable design solutions to minimize the negative impacts and enhance the positive impacts on the environment.

A green building rating system is an evaluation tool that measures environmental performance of a building through its life cycle. It usually comprises of a set of criteria covering various parameters related to design, construction and operation of a green building. Each criterion has pre-assigned points and sets performance benchmarks and goals that are largely quantifiable. A project is awarded points once it fulfils the rating criteria. The points are added up and the final rating of a project is decided. Rating systems call for independent third party evaluation of a project and different processes are put in place to ensure a fair evaluation. Globally, green building rating systems are largely voluntary in nature and have been instrumental in raising awareness and popularizing green building designs. The most representative building environment assessment schemes in India that are in use today are Leadership in



Energy and Environmental Design (LEED) and Green Rating for Integrated Habitat Assessment (GRIHA).

GRIHA, the national green building rating system, was developed by TERI after a thorough study and understanding of the current internationally accepted green building rating systems and the prevailing building practices in India. The primary objective of the rating system is to help design green buildings and, in turn, help evaluate the 'greenness' of buildings. The rating system follows best practices along with national/ international codes that are applicable to the green design of buildings. The green building rating system devised by TERI is a voluntary scheme. It has derived useful inputs from the building codes/guidelines being developed by the BEE (Bureau of Energy Efficiency), the MNRE (Ministry of New and Renewable Energy), MoEF (Ministry of Environment and Forests), and the BIS (Bureau of Indian Standards). The rating system aims to achieve efficient resource utilization and to enhance resource efficiency and quality of life in buildings. GRIHA has been adopted as a NRS (National Rating System) under the MNRE, Government of India, as of 1 November 2007. The MNRE has set up a technical advisory committee comprising of eminent professionals.

## 2. METHODOLOGY

### 2.1 Methodology of GRIHA software in green building

A NAC (National Advisory Council) has been constituted by the MNRE and is convened by the Advisor of the Ministry. It comprises eminent architects, senior government officials from the Central Ministry, the BEE, the Central Public Works Department, and select state nodal agencies; representatives from the IT sector, real estate sector and developers; and representatives from ADaRSH (Association for Development and Research of Sustainable Habitats-GRIHA secretariat) and TERI. The NAC is chaired by the Secretary, MNRE, and co-chaired by the Dr R K Pachauri, Director-General, TERI. The NAC provides advice and direction to the NRS and is the interface between the MNRE and ADaRSH (GRIHA secretariat). Its broad functions are as listed below.

- Guide the administrative structure for GRIHA
- Decide a fee structure
- Endorse the rating
- Recommend incentives and awards by the Government of India/state governments
- Endorse modifications/upgrades periodically

The system has been developed as 'design and evaluate' new buildings (buildings that are still at the inception stages). A building is assessed based on its predicted performance over its entire life cycle — from inception to

operation. The stages of the life cycle that have been identified for evaluation are pre-construction, building design and construction, and building operation and maintenance.

The prime resources that are considered in this section are land, water, energy, air, and green cover. Building operation and maintenance stage (issues of operation and maintenance of building systems and processes, monitoring and recording of consumption, and occupant health and well-being, and also issues that affect the global and local environment).

Except for industrial complexes, all buildings – offices, retail malls, institutions, hotels, hospitals, health-care facilities, residences, and multi-family high-rise buildings – in the pre-design/design stage are eligible for certification under GRIHA. ADaRSH officials can examine project documents to help you establish whether project is eligible for GRIHA rating and render requisite assistance for registration.

### Registration

Building project may register through the GRIHA website (<http://www.grihaindia.org>)

- For ease of adoption, registration should be completed at the onset of the project cycle, as there are several important issues that need to be addressed at this stage.
- The registration process allows for access to essential information such as
  - Application forms
  - List of required submissions
  - Score points
  - The weightage system and
  - Online documentation

### Evaluation

Project evaluation happens at two broad stages.

1. Pre documentation stage – a team from ADaRSH along with the client's Integrated Design Team meet and determine the points being targeted by the project, as soon as the building project is registered, during the orientation workshop.
2. Post documentation stage – all necessary proof through documents for the points targeted under various criteria is submitted and then evaluated by third party regional evaluators, to determine final rating that shall be awarded to the project.

During the construction phase of the project, members of the ADaRSH team carry out three due diligence visits, to check on-site compliance of relevant GRIHA criteria.

Once the necessary documentation is uploaded, and systems commissioned on site, the building is evaluated and rated in a three-tier process.

- The preliminary evaluation is done by a team of experts from ADaRSH.
  - The team reviews the mandatory points and checks for compliance. The project is rejected if mandatory criteria are not complied with.
  - The team then evaluates the optional criteria and estimates the total number of achievable points.
- All compliance documents are vetted through the appraisal process as outlined by GRIHA.
- The evaluation report is given to members of an evaluation committee, comprising renowned external experts in building and landscape design, lighting and HVAC design, renewable energy, water and waste management, and building materials.
- The members independently review and award points.

- A provisional GRIHA rating is awarded after evaluation of documents submitted.

### **Rating**

The final score is presented to the National Advisory Committee comprising eminent personalities and renowned professionals in the field, for approval and award of the final rating.

- The final GRIHA rating is awarded after receipt and evaluation of the post occupancy performance audit reports. The audit is conducted after 1 year of building occupancy.
- The rating awarded is valid for a period of five years from the commissioning of the building.
- GRIHA reserves rights to conduct random audits of any criteria for which points have been awarded.
- Queries on rating may be sent to <admin@grihaIndia.org>, and will be responded to within two working days.

The registration fee can be calculated based on the following formula

**TABLE I: Registration fee based on built-up area**

Built-up area*	Registration fee (excluding tax)
<5000 m ²	Rs.3, 14, 000 [Rupees three lakh and fourteen thousand only]
>5000 m ²	(Rs.3, 14, 000) + (Rs.3.75 per m ² above 5000) Rupees three lakh and fourteen thousand, plus Rupees three and seventy five paise per square meter over 5000
(*Excluding basements)	

### **Cost Break-up**

The registration fee includes the following:

1. A one-day workshop for the project team to explain the rating system and allocate roles and responsibilities for the consultants involved. If the workshop is outside NCR of Delhi, the cost of travel, board and lodging is borne by the client.
2. Evaluation fee which is paid to the external evaluators who assess the project submittals.

### **Due diligence visits related expenditure**

The travel and stay cost of two members of GRIHA team for three visits to site is to be borne / reimbursed by the client.

### **2.2 Scoring method and award of rating**

The registration form shall request details of top soil, tree cover, hot water requirement, waste water generation,

organic solid waste generated. The selectively applicable criteria cannot be attempted by projects that do not meet the threshold values for the selectively applicable criteria. The project shall be rated on applicable criteria only and shall be given percentage scoring. The information will be provided to ADaRSH (GRIHA secretariat) by the applicant and the Secretariat will decide the points which are applicable or inapplicable for the particular project.

**TABLE II:  
GRIHA rating system point distribution**

New Rating Thresholds	GRIHA Rating
25 – 40	1 Star
41 – 55	2 Star
56 – 70	3 Star
71 – 85	4 Star
86 or more	5 Star

**TABLE III: Details of sections and point distribution**

Section	Criterion No	Criterion Name	Max. Points
Site Planning	1	Site Selection	1
	2	Low-impact design	4
	3	Design to mitigate UHIE	2
	4	Site Imperviousness Factor	1
Construction Management	5	Air and Water pollution control	1
	6	Preserve and protect landscape during construction	4
	7	Construction Management Practices	4
Energy	8	Energy efficiency	13
	9	Renewable energy utilization	7
	10	Zero ODP materials	0
Occupant Comfort and Well Being	11	Achieving indoor comfort requirements (visual/thermal/acoustic)	6
	12	Maintaining good IAQ	4
	13	Use of low - VOC paints and other compounds in building interiors	2
Water	14	Use of low flow fixtures and systems	4
	15	Reducing landscape water demand	4
	16	Water Quality	2
	17	On-site water reuse	5
	18	Rainwater Recharge	2
Sustainable Building Materials	19	Utilization of BIS recommended waste materials in building structure	6
	20	Reduction in embodied energy of structure	4
	21	Use of low- environmental impact materials in building interiors	4
Solid Waste Management	22	Avoided post-construction landfill	4
	23	Treat organic waste on site	2
Socio-Economic Strategies	24	Labour safety and sanitation	1
	25	Design for Universal Accessibility	2
	26	Dedicated facilities for service staff	2
	27	Increase in environmental awareness	1
Performance Monitoring and Validation	28	Smart metering and monitoring	8
	29	Operation, Maintenance Protocols	0
	30	Performance Assessment for Final Rating	0
	31	Innovation	4

### **2.3 Sample example for better understanding of GRIHA tool**

The technical feasibility study has been carried out for the residential building located in Ahmadabad.

Table shows details of the building and assumptions made during analysis.

**TABLE IV: Details of sample building**

Sr No	Description		Values	unit
1	Sample Building	Climate zone	Hot and dry	
		Apartment type	3BHK	
		Sample building	3BHKapartment A	
2	Building Geometry	Internal parking area	200	m ²
		Common area	170	m ²
		Numbers of storeys	12	
3	Apartment Area	Apartment area	6432	m ²
		Conditioned area	3120	m ²
4	Apartments	No of apartments	1	
		Average occupants	5	
		Internal heat gains	High	
5	Building characteristics			
	1, Inertia of building	External walls	Light	
		Internal walls	Light	
		Suspended ceilings	No	
	2.ventilation by openings	Openings in	Two/more orientations	
	3.Thermal bridges	Building includes	Few	
	4. Airtightness	Building	Un-tight	
	5.Wind shielding	Wind shielding	No	
6.	Building Lighting			
	1. Internal lighting for apartment area	Lighting power density	1.50	W/m ²
		Lighting control option	Manual On/Off	
	2. Common area lighting (stairs, lobby, etc)	Lighting power density	6.50	W/m ²
		Lighting control option	Manual On/Off	
	3.Common lighting for internal parking area	Lighting power density	2.20	W/m ²
		Lighting control option	Manual On/Off	
7.	Cooling			
	1.Split AC	Number of installed units	144	
		BEE star rating	3star	
		EE rating	2.90	W/W
8.	Heating	No heating		
9.	Decentral hot water			
	1. Electric geyser	Storage capacity	15	
		Number of installed units	96	
		BEE star rating	3star	

### 3. RESULT

The simulation result has been shown into the below figure which indicates that cooling energy contributes highest energy consumption per square meter per year during the May to October month. It has been also noted that the

current average energy consumption of the building shows 38% energy savings. This result will help to get the GRIHA rating points under the section of Energy, sub sector energy efficiency, as per GRIHA ratings building is eligible for 5 points under the section of 8.1.5.

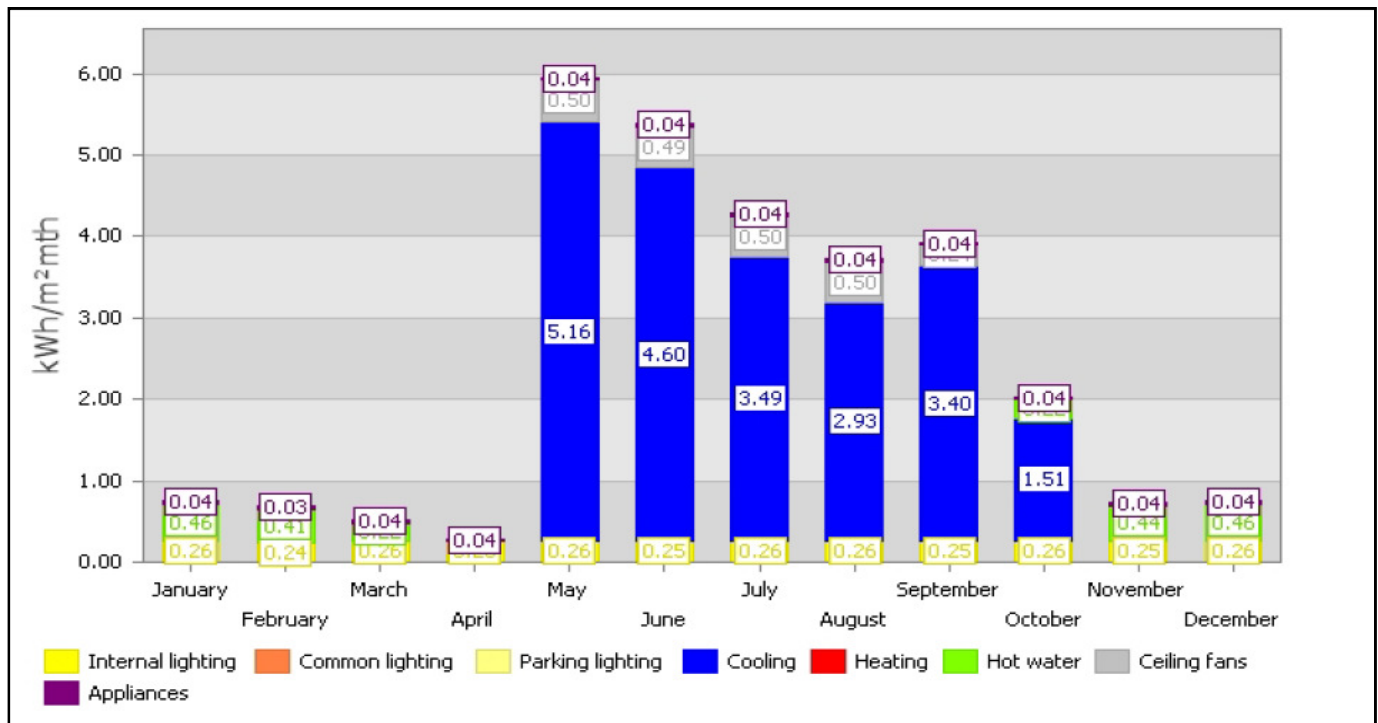


Fig. 1. Monthly Delivered Energy-1

2.11.2 Delivered Energy

Name	Total	Internal lighting	Common lighting	Parking lighting	Cooling	Heating	Hot Water	Ceiling fans	Appliances
January [kWh/m²mth]	0.76	0.26	0.00	0.00	0.00	0.00	0.46	0.00	0.04
February [kWh/m²mth]	0.68	0.24	0.00	0.00	0.00	0.00	0.41	0.00	0.03
March [kWh/m²mth]	0.52	0.26	0.00	0.00	0.00	0.00	0.22	0.00	0.04
April [kWh/m²mth]	0.29	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.04
May [kWh/m²mth]	5.96	0.26	0.00	0.00	5.16	0.00	0.00	0.50	0.04
June [kWh/m²mth]	5.38	0.25	0.00	0.00	4.60	0.00	0.00	0.49	0.04
July [kWh/m²mth]	4.29	0.26	0.00	0.00	3.49	0.00	0.00	0.50	0.04
August [kWh/m²mth]	3.73	0.26	0.00	0.00	2.93	0.00	0.00	0.50	0.04
September [kWh/m²mth]	3.93	0.25	0.00	0.00	3.40	0.00	0.00	0.24	0.04
October [kWh/m²mth]	2.03	0.26	0.00	0.00	1.51	0.00	0.22	0.00	0.04
November [kWh/m²mth]	0.73	0.25	0.00	0.00	0.00	0.00	0.44	0.00	0.04
December [kWh/m²mth]	0.76	0.26	0.00	0.00	0.00	0.00	0.46	0.00	0.04
Total [kWh/m²yr]	29.06	3.08	0.00	0.00	21.08	0.00	2.21	2.24	0.44

Fig. 2. Monthly Delivered Energy-2

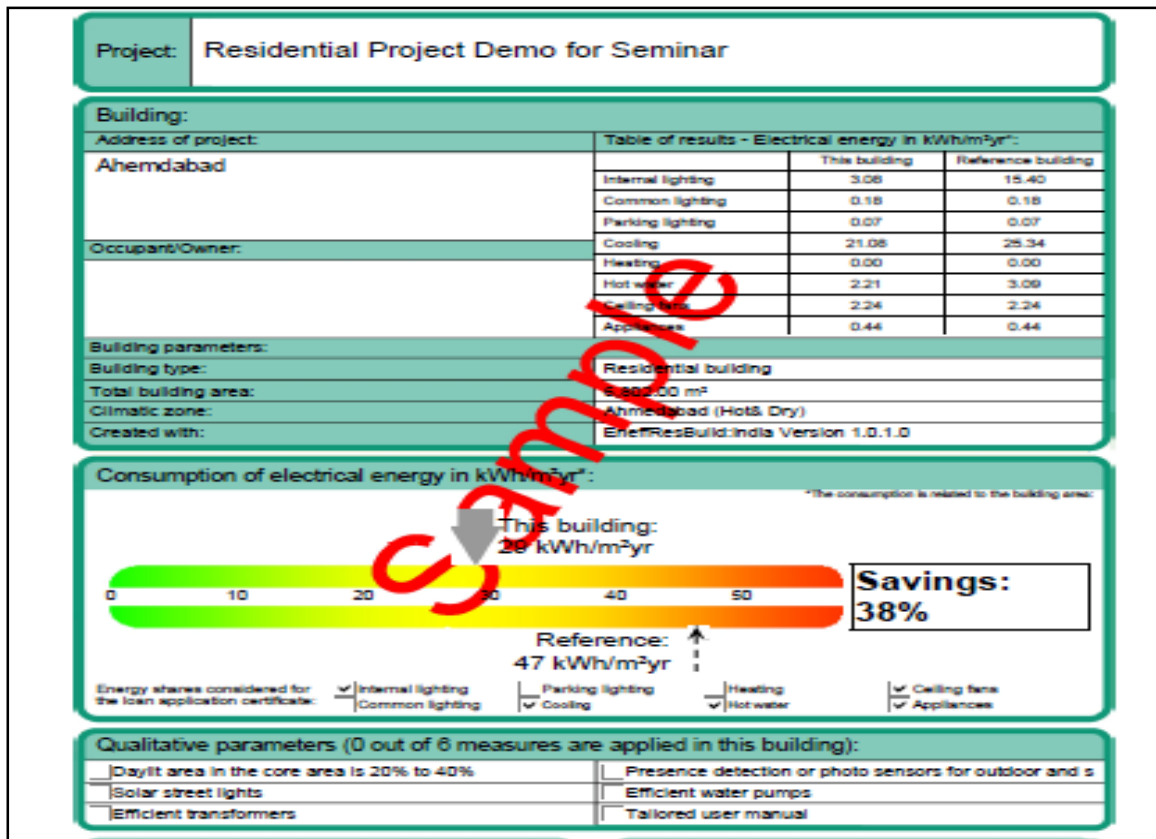


Fig. 3. Consumption of electrical energy for sample building

Deviations with respect to reference building			
Internal lighting for apartment area			
Lighting power density(LPD)	W/m ²	1.50	7.50
Cooling			
EE Rating	W/W	2.90	2.50
Hot water			
BEE Star rating	-	3 Star ***	1 Star *

Fig. 4. Deviations with respect to reference building

#### 4. CONCLUSION

There are many factors which have to be considered while constructing a green building. It is very necessary to know how effective a building is in term of its environment friendliness. As from abovestudy of GRIHA rating system some suitable points for green building which is simple and effective is suggested for small contractors to achieve green agenda simply and economically. This point is an

integration of various points such as it carries the advantages of system where as it overcomes the individual shortcomings.

This tool has been very vital to the identifying the saving which can be achievable through different strategies passive or active technologies, which can be useful for the GRIHA Energy Saving Sectors. Currently more than 1000 projects are under GRIHA certification projects having the 40

square million area. GRIHA certification is mostly appropriate for the pre design and design phase.

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SECTION – XI  
TOTAL QUALITY MANAGEMENT

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# A Comparative Study of Evaluation Criteria of National Quality Award: A Review of Literature

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**Abstract:** The purpose of this paper is to present a comparative study of evaluation criteria of nine national quality awards model to identify their common features, differences and weighting on each one. This study is based on a literature review using the internet and research database (Emerald). The following discussion is mostly based on the author's findings, compared with the most common practices. Literature revealed that most of the National Quality Awards Model start with the criteria "Leadership" and end with "Result". First, briefly describes the nine quality awards: Malcolm Baldrige National Quality Award from the USA, European Quality Award, Deming prize of Japan, the Rajiv Gandhi National Quality Award, the Golden Peacock National Quality Award, the Ramkrishna Bajaj National Quality Award and CII EXIM Business Excellence Award from India, the Australian Business Excellence Award and the South African Excellence Award. Second, present the weighting on evaluation criteria. Finally performs a comparison between the major awards and the Indian Quality Awards in order to identify the similarities and differences among them.

**Keywords:** National Quality Award, India, Evaluation Criteria

## 1. INTRODUCTION

National Quality Awards and the Business Excellence Models that recognize excellent organizational performance have emerged as a significant component of the productivity and quality promotion strategies of many countries. NQAs and BEMs principal aim is to promote, recognize and communicate best practices. It usually consists of a framework, which includes core values and principles of excellence. These principles are the foundation to build the framework, consisting of a certain number of evaluation criteria. The establishment of comprehensive sets of criteria to evaluate award applicants has provided businesses with a consistent set of standards by which they can evaluate and monitor quality performance.

This paper presents background and compared nine NQAs / BEMs (five Asian, one North American, one Oceania, one European and one African) based on evaluation criteria framework. They are:

- 1) The Deming Prize
- 2) European Quality Award
- 3) Malcolm Baldrige National Quality Award
- 4) Australian Business Excellence Award
- 5) South African Excellence Award
- 6) Rajiv Gandhi National Quality award
- 7) IMC Ramkrishna Bajaj National Quality award
- 8) Golden Peacock National Quality award
- 9) CII EXIM Business Excellence Award

When these award programs were compared, significant similarities found in the evaluation criteria used for assessing award applicant.

## 2. LITERATURE REVIEW

Specifically, the aim of this research was to a global vision regarding the quality award. The literature was reviewed using the principles of deductive reasoning. Salient findings regarding the evaluation criteria are outline in the table. I.

TABLE I

Author	Salient findings regarding Evaluation Criteria
Bohoris (1995)	The Deming Prize framework focused on the implementation of principles such as process analysis, statistical methods and quality circle. The Malcolm Baldrige principle behind its award criteria is that leadership drives the activities towards excellence in quality results and customers satisfaction. The rationale for the EQA model is that the results achieved through leadership driving the enablers, leading to excellence in business results.
Laszlo (1997)	U.S and Canadian national quality award of 1996 and 1997 compared were MBNQA overall points related to results was increased by 40, which

Author	Salient findings regarding Evaluation Criteria
	represents a relative weighing factor of 4 percent out of the 1000 point total. While in Canada award for excellence, the outcomes are gathering into seventh criteria, organizational performance with 240 points.
Puay et al. (1998)	The Rajiv Gandhi National Quality Award assigned the highest weight age of 13 percent on impact of society while the Brazil National Quality Award assigned the lowest weight age of 2 percent.
Vokurka et al. (2000)	Differences exist in the point allocations placed on each criterion, business results have the greatest weight for Malcolm Baldrige Award, customer satisfaction for the EQA, organizational performance for the Canadian Award and people or processes for the Australian Award, and however all of the checkpoints in the Deming prize are equally weighted.
Cauchick Miguel (2001)	The major internationally recognized quality awards of the European community, Japan, the USA, Canada and Australia use evaluation criteria, which are very similar in nature, even when comparing them to the Brazilian one.
Eskildsen et al. (2001)	The criteria “customer results” and “people results” are perceived as more important than “society results” and “key performance results”.
Tan (2002)	Factors like, Government and private sector support, Adoption of model, the importance of SMEs Quality maturity level, Cultural differences, Global competitiveness factors, Assessment process, Selection of examiners, Levels of award recognition, Award promotion and Evaluation of the award program serves as recommendations for the development of other NQAs.
Eskildsen et al. (2002)	The empirical excellence model for 2001 is not in accordance with the results from the previous years and this suggests that the criterion weights of the EFQM excellence model are not stable and generic quantities that can be applied uniformly across time.
Khoo and Tan (2003)	The overlapping core concepts found in the MBNQA and JQA are social

Author	Salient findings regarding Evaluation Criteria
	responsibilities, employee education, strong customer-focus and continuous improvement.
Sharma and Talwar (2007)	The difference between UBEM and existing BEM is that while BEM consider purpose of business is creation of wealth and enhance profitability, UBEM emphasizes that it is only a means to attain universal wellbeing for sustainable success.
Kumar (2007)	During the 13 years, the emphasis of both the Deming Prize and the MBNQA has shifted from technical quality to excellence of all organizational processes.
Talwar (2009)	The integration of excellence models with human values through the evolution of a charter of “global minimum common values” by model custodians, the GEM Council and corporate leadership will lead to an exponential growth in business and prosperity for all stakeholders.
Talwar (2011)	Identified Customers, People and Business results as the core criteria, Process, Leadership, Strategic planning and Knowledge and information management as Internal environment criteria, and Society and Suppliers/partners as Goodwill criteria for ensuring sustainability.
Arumugam et al. (2011)	Information can directly affect Policy & Strategy, People, Processes and Customer results. Information criterion has several relations with dimensions of EFQM model. Information can be integrated in EFQM framework as a separate criterion to support the system.
Singla et al. (2011)	The implementation of ten best critical success factors (CSFs) which are highly emphasized by most of the NQA’s 7 researchers will add to the competitive position of a manufacturing firm and thus provides a firm with strategic advantage in the marketplace.
Sampaio et al. (2012)	In the future a single consensual excellence model to be developed and applied all over the world, since all models do share a common set of values, principles and criteria.

### 3. OVERVIEW OF THE AWARDS

#### 3.1 The Deming Prize (DP)

The Deming Prize was established in 1951 in commemoration of the late Dr. William Edwards Deming Who contributed greatly to Japan's proliferation of statistical quality control after the World War II. It is one of the highest awards on TQM (Total Quality Management) in the world. Japanese Union of Scientists and Engineers (JUSE) carry out the process of receiving the application and presentation of awards.

#### 3.2 The European Quality Award (EQA)

In 1990, the European Foundation for Quality Management (EFQM) with support from the European organization for quality and the European commission began developing the European Quality Award. In 1991, the EFQM launched the European Quality Award to recognize Europe is best performing organization, whether public, private or non-profit. EFQM is a global non-for-profit membership foundation with it is headquartering in Brussels, Belgium. The method of evaluation used with the Excellence Model is called RADAR and consists of four steps: Decide on the Results the organization is aiming for; Develop an integrated set of sound Approaches to attain the results; Deploy approaches in a systematic way; Asses and Refine the approaches by monitoring and analyzing the results achieved. The RADAR logic can be combined with the EFQM Excellence Model to create a robust assessment of any organization.

#### 3.3 Malcolm Baldrige National Quality Award

In 1987, Congress Established the Baldrige Award and named after the late Secretary of Commerce Malcolm Baldrige, a proponent of quality management. The U.S. Commerce Department's National Institute of Standards and Technology manages the award and ASQ administers it. It was design to raise awareness of quality management and recognize U.S. companies that have implemented successful quality-management systems. The President of the U. S. presents it annually to organizations that demonstrate quality and performance excellence. The education and healthcare categories was added in 1999. A government and nonprofit category was added in 2007.

#### 3.4 Australian Business Excellence Awards

Australian Quality Awards founded in 1998 to promote, nurture, recognize and celebrate organizational excellence in all its forms. ADRI (Approach, Deployment, Results and Improvement) assessment methodology employed for assessment of organization. There are two levels of entry to apply for the award:

#### 3.5 South African Excellence Award

The South African Excellence Award established in 1998 and afforded the opportunity to encourage a philosophy of

best practice in all areas of business, to foster competitiveness and enhance service to our customers.

#### 3.6 IMC Ramkrishna Bajaj National Quality Award

In 1995 the IMC (Indian Merchant Chamber) Ramkrishna Bajaj National Quality Award trusts instituted jointly by the IMC and the House of Bajaj. In 1997 the first award cycle was began to encourage the Indian organizations to adopt a performance excellence model to bring in improvements.

#### 3.7 Rajiv Gandhi National Quality Award

It was instituted by the Bureau of Indian Standards (BIS) in 1991, with a view to encouraging Indian manufacturing and service organizations to strive for excellence and giving special recognition to those who are considered to be the leaders of quality movement in India. This award is intended to generate interest and involvement of Indian Industry in quality programs, drive our products and services to higher levels of quality and equip our Industry to meet the challenges of domestic and International markets. The award been named after Late Prime Minister Rajiv Gandhi.

#### 3.8 Golden Peacock National Quality Awards

The Institute of Directors (IOD) instituted the Golden Peacock National Quality Award Scheme in 1991 to encourage Total Quality improvements in both manufacturing as well as service organisations in India. The Golden Peacock National Quality Award, named after India's national bird the "Peacock", and is awarded every year. The Golden Peacock National Quality Award would be given separately for manufacturing and service sector organisations, under the following categories:

Normal Categories

- 1) Large Enterprises: Annual Turnover Rs 300 crores & above
- 2) Medium and Small Enterprises: Annual Turnover less than Rs 300 crores

Sector covered: Manufacturing, Service, Government, Public & Private

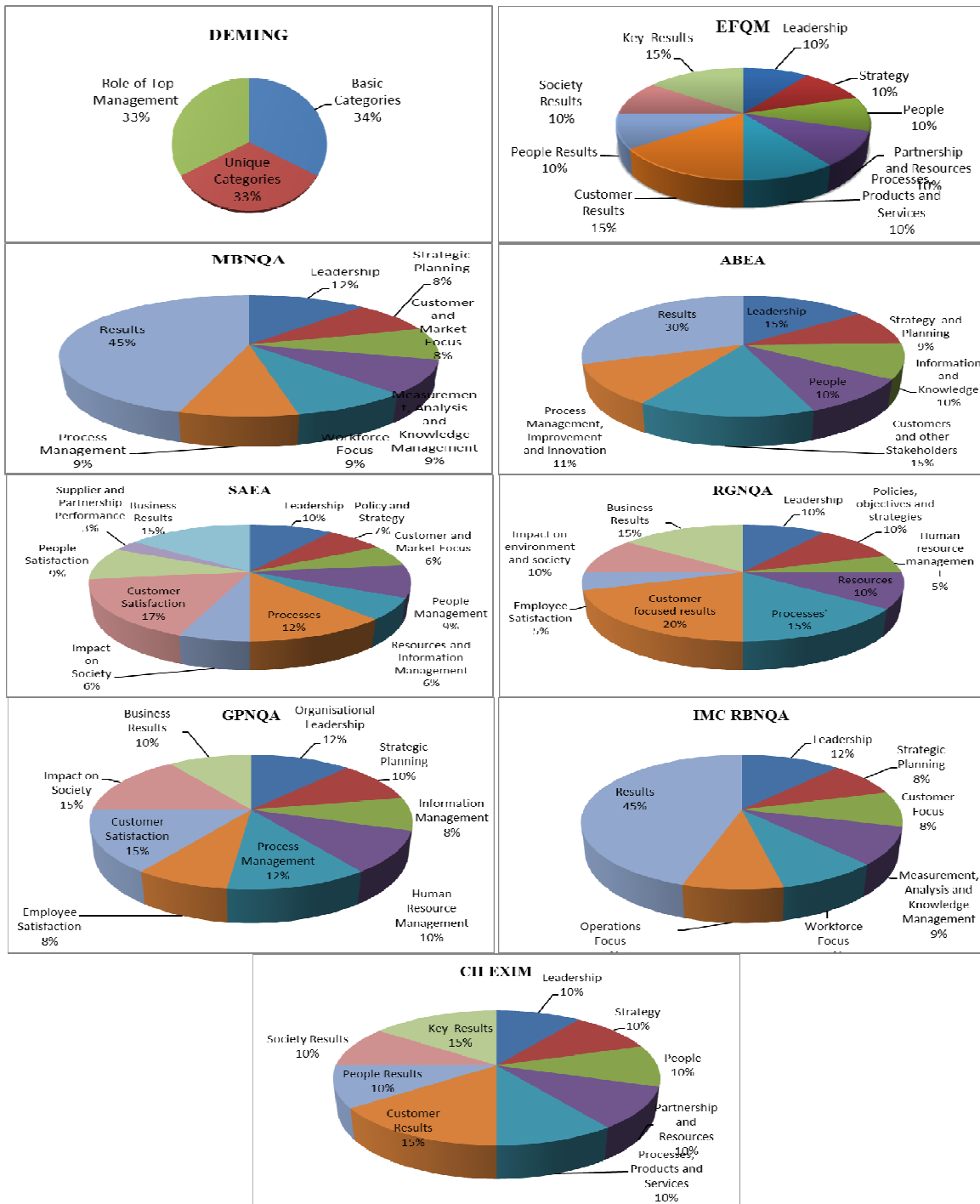
#### 3.9 CII EXIM Business Excellence Award

CII (Confederation of Indian Industry) is a non-government, not-for-profit, industry led and industry managed organization, playing a proactive role in India's development process to promote awareness of Quality for enhancing the Competitiveness of India. The CII works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes. CII and the Export Import Bank of India have joined together, in 1994, for promoting excellence among Indian Industry through the CII-EXIM Bank Award for Business Excellence. The Award is based on the internationally recognized EFQM Excellence Model.

#### 4. EVALUATION CRITERIA

The evaluation criteria of the nine quality awards are shown in the form of pie chart. They are the parameters on the

basis of which the applying organization evaluated for the award process.



Source: Union of Japanese Scientist & Engineers (2012), European Foundation for Quality Management (2010), MBNQA criteria for performance excellence (2008), Sai global (2012), National Chamber of Commerce (2012), Exploring a Causal Model for the Brazilian National Quality Award (2010), SAEM (2008), Rajiv Gandhi National Quality Award (2010), Golden Peacock National Quality Award (2010), IMC Ramkrishna Bajaj National Quality Award (2012), CII EXIM Bank Award for Business Excellence (2012).

## 5. SCORING METHODOLOGY

EFQM (RADAR)	MBNQA (ADLI)	ABEA (ADRI)	SAEA	RGNQA (ADLI)	GPNQA (ADR)	IMC RBNQA (ADLI)	CII EXIM (RADAR)
Result	Approach	Approach	Approach	Approach	Approach	Approach	Result
Approach	Deployment	Deployment	Deployment	Deployment	Deployment	Deployment	Approach
Deployment	Learning	Result		Learning	Result	Learning	Deployment
Assessment	Integration	Improvement		Integration		Integration	Assessment
Review							Review

## 6. CONCLUSION

From the literature review it has been observed that the Indian quality award IMC RBNQA and the CII-EXIM model fully adopted the MBNQA model and EFQM respectively. The evaluation criteria of RGNQA and GPNQA are similar to that of EFQM only difference lies in the weighting. When the national quality award of India the RGNQA and the GPNQA are compared on the enabler and result criteria with the EFQM, it has been found that the each one are allotted 500 points. Also literature revealed that the Indian National Quality Awards are not in concurrence to suit for the small scale industry with 100 or fewer employees or annual sales turnover of less than 10 crores. However, this can only be achieved by formulating the quality award with minimum application fee. Furthermore, care must be taken to ensure that these models possess the required parameters that should be properly applicable to small scale industry.

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# Application of Quality Function Deployment for the Design Development of an Impeller

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**Abstract:** Nowadays, competition among the industries has become more strong in the global market. For the development of business globalization, companies face challenges from both national and international competitors. To survive in the huge competition and changing market company dependent on its capacity to identify new customer needs and to develop a new product. In 1966, Yoji Akao introduced the concept of QFD in Japan. According to Akao, QFD is a method to translate customer needs into the quality characteristics in order to improve quality for an existing product to develop a new product that satisfy the customers' needs. Hence, this paper describes how a quality plan can be determined for a product Impeller by using Quality Function Deployment (QFD) technique. From the result of QFD applied to an Impeller we short out the parameters which are required for the modification of an impeller model according to the voice of customer (VoC) or customer's needs.

**Keywords:** Customer needs, HoQ matrix, Impeller, QFD, Technical needs

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## 1. INTRODUCTION

Quality function deployment (QFD) is one of the total quality management [TQM] technique. It is a customer oriented approach to product improvement. It is introduced in Japan in 1960's by Yoji Akao. QFD is a quality tool that helps to translate the Voice of the Customer (VoC) into new products that truly satisfy their needs. VoC is gathered by variety of ways such as interviews, market surveys, customer specifications, direct discussion, etc. This customer needs are then summarized in a house of quality matrix. These matrices are used to translate what's or customer needs into how's or technical characteristics to satisfy needs. QFD is applied in the stages of design phase so that what customer wants are included into the final product. QFD consist of total six elements those are: determine customer requirements; determine technical requirements; relationship between those needs; target values; correlation ships between technical needs and a quantification of the importance of the requirements. QFD methodology consist of total four phases those are the product planning (HoQ matrix), product designing, process planning and process control.

## 2. LITERATURE SURVEY

This part covers the literature on Quality Function Deployment [QFD] and the different aspects of it. The purpose of literature review is to provide background information on the issue to be considered in this paper and to highlight the importance of the present study.

So-Hyun Park et al. (2012) explains the requirements of the American customer for the Korean dish "Bulgogi" which is international popular dish. A customer survey and an expert

opinion survey were conducted for US customers. In order to improve Bulgogi for international customer's appetites, marketing analysis should be performed. In this research QFD was applied in six main steps. After applying QFD, we select the five most important parameters for improving the dish, those are "localization of Bulgogi menu, control of marinating time, improvement of cooking and serving process, development of recipe by parts of beef, and strong vegetable component".

A.S. Khangura and S.K. Gandhi, (2012) proposed that this quality improvement is based on the feedback of customer about new and existing product in market and from benchmarking of competitors. In this paper, QFD apply to a product like refrigerator to design development and implement of the product quality. After applying QFD to the product like refrigerator, we find out the most important parameters and functions from customer point of view to develop the design of refrigerator. Those total seven important factors are, "Air flow Type, Service life, Energy consumption, Number of Shelves and Boxes, Number of Refrigerator Door Shelves, Humidity control and Dimension".

Burcu Devrim Ictenbas and Hande Eryilmaz, (2011) explains that QFD is the methodology to translate customer requirements into the service characteristics. The purpose of the study this paper is to evaluate different teaching methods in perspective of employer's expectations using the QFD approach. In the industry the qualified workers are needed by the employers. Therefore, Universities assume the responsibility to educate the students in accordance to the expectations of employers in various sectors like manufacturing and services sectors. After applying last step

of QFD methodology we select total three teaching methods which meets the employers expectations, Those effective teaching methods are "lecture, case study and project work".

J. Viaene et al. (1999) explains that the QFD apply to chocolate for integrating different research methods within the house of quality model. Chocolate serves as an example of a very complex product, whose final quality depends on various fundamental and extrinsic interactions. The final concept relates to filled chocolate that, according to definition, a chocolate with filling covered by chocolate covertures of not less than 15%. In this, there are total five steps consisted which was developed in association with the house of quality matrix. After applying those five steps, we get the four factors that are most important to the quality improvement of chocolate. those are, "wonderful and clear chocolate aroma, sweet taste, smooth texture and luxurious melt-in-the-mouth quality". Liviu Moldovan, (2014) explains that the QFD is used to understand the customer needs in order to select the suitable characteristics and their 'weight', for new product design in mineral water company. QFD is also used to develop a new soft drink, enabling the company to enter the new market successfully. The "Neutral Aqua Company" invent the new soft drink which meets the customer requirements that product named as "Limio". In this they apply the QFD to improve the quality of the Limio. After applying QFD, it gives the integrated results those are "Reducing the amount of sugar, Acidity, Soluble substance, Citrus pulp content". This are the important requirements to improve the Limio to be a successful soft drink in market as in "Romanian market".

Irem Dikmen et al.(2004), examine the applicability of QFD as a strategic decision-making tool after the construction stage of a housing project to determine the best marketing strategy, to make a comparison between the performances of different competitors and to transfer the experience gained from the current project to the forthcoming projects for the housing complexes mainly within the region of Ankara. The total area of the high-rise housing complex was 23 000m² where 11 388m² was utilized for social facilities and housing units. The remaining area was reserved for recreational purposes. QFD methodology was differentiate in the six section. This gave the integrated result that total five most important technical measures which contributed to the success of the project were, " location of the housing complex, functional architectural layout of the apartment units, total size of each apartment unit, security system/professional security team and finally, area reserved for recreational purposes/good sight".

### 3. METHODOLOGY

The basic Quality function deployment methodology involves four basic phases that occur over the line of the product improvement process. Those are;

#### 3.1 Product planning (HoQ matrix)

It is also called as "House of Quality" matrix. In this we plan the product according to the customer requirements or needs which are taken by the market survey, and from those needs we choose some of the important needs as an objectives.

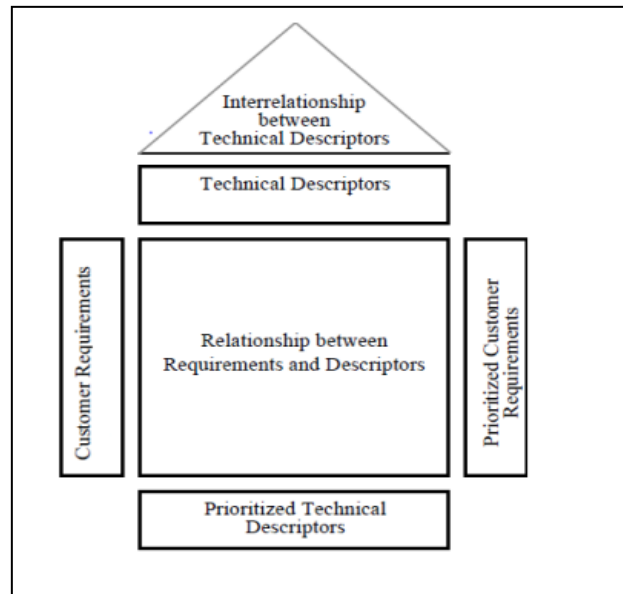


Fig. 1. House of quality matrix

#### 3.2 Product designing

The second phase is product designing which is lead by the engineering department. This phase requires creativity and innovative team ideas. During this phase product concepts are created and specifications of part are acknowledged.

#### 3.3 Process planning

After product design, process planning comes next & is lead by manufacturing engineering. During this phase, required manufacturing processes, machines and tools are flowcharted and process parameters or target values are documented.

#### 3.4 Process Control (Production)

Final phase is process control or production planning. In this phase performance indicators are created to monitor the production process, maintenance schedules & skills training for operators. Also, the decisions are made as to which process poses the most risk & controls are put in place to prevent failures.

#### 3.5 Approach for QFD of Impeller

For the design of an Impeller, QFD consist of following steps :



**Step 1: List of customer requirements and assign a weight indicating the relative importance of each requirement in view of customers**

The First step of this work is to get customer requirements from open market survey. The method of collecting information about the VOC is through the questionnaire from the open market survey. The users are selected from open market. Here, the survey containing 14 questions in the form of VOC data collection & those are:

- |                        |                     |
|------------------------|---------------------|
| 1] Weight              | 8] Modularization   |
| 2] Size                | 9] Ease of assembly |
| 3] Ease of maintenance | 10] Reliability     |
| 4] Availability        | 11] Aesthetic       |
| 5] Ease of clean       | 12] Service         |
| 6] Warranty            | 13] Trading         |
| 7] Technological Risk  | 14] Accessibility   |

Customer importance rating is to be given to obtained the high value rating characteristics of customer preference. Here, we gave the customer importance rating from 1 to 5 i.e.1 is highest customer demand and the 5 is lowest customer demand.

**Step 2: List of technical characteristics to derive measures to assure that those customer requirements are satisfied**

The second step of this work is to get manufacturing requirements by manufacturer engineers. The Systems Engineering Department derive measures to assure that the customers' demands and company demands are satisfied. In this step, engineering characteristics are derived from expert's opinion & the surveys are required to fulfill customer's requirements. Here, the technical requirements of an impeller part are:

- |                               |                                                         |
|-------------------------------|---------------------------------------------------------|
| 1] Constant RPM to motor      | 8] Holes                                                |
| 2] Less energy consumption    | 9] Capacity                                             |
| 3] Cost                       | 10] Casting (PDC)                                       |
| 4] Draft angle & no. of vanes | 11] Production Rate                                     |
| 5] Reduce design time         | 12] Mach inability                                      |
| 6] Thickness of vanes         | 13] Material                                            |
| 7] Total life span            | 14] Regulate uniform flow of oil through impeller vanes |

**Step 3: Develop relationship between customer requirements and the quality characteristics**

The relationship matrix is used to represent graphically the degree of influence between each technical descriptor and

each customer requirement in order to identify important product properties. The relationships is rated on a scale consisting of 0, 1, 3 and 9 where,

- 9 - Strong relationship
- 3 - Medium relationship
- 1 - Weak relationship and
- 0 - No relationship

**Step 4: Develop interrelationship among the quality characteristics**

This matrix is about to determining the correlation between each of the quality characteristics. This engineering characteristics are derived from expert's opinion survey. Those are required to fulfill the customer's requirements. Once the technical characteristics were obtained, then the correlation matrix was developed to determine the relationships between parameters, since they are frequently correlated to each other in a product. Here, the correlation matrix shown with the help of below signs:

- + - Positive Correlation
- △ - Weakly Positive Correlation
- - Negative Correlation
- Blank - No Correlation

**Step 5: Planning matrix**

The planning matrix would be more useful if it could be based on real strategic marketing information. In this matrix market data strategic goals setting for the new product. There is a series of priorities for the customer requirements that are based on their importance to be development team's requirements are ordered by priorities. In this matrix, our product compared with the other competitors of the market. Here, we compared our component impeller with:

- Competitor- 1 Swaraj Engines and
- Competitor- 2 Mahle Engine Components India Pvt. Ltd.

**Step 6: Technical matrix**

The next step in completing the HoQ was establishing the absolute and relative importance of each engineering characteristic. The absolute importance weights were calculated by multiplying the weight of customer requirements by the numerical relationship between the requirements and characteristics, then followed by summation. The relative importance was then calculated based on the absolute importance. The final importance rating of "Hows" was determined based on the technical difficulty, and the correlation matrix. Considering these aspects, the final importance rating was computed as shown in below fig. which gives the results required to improve the design and quality of part Impeller.

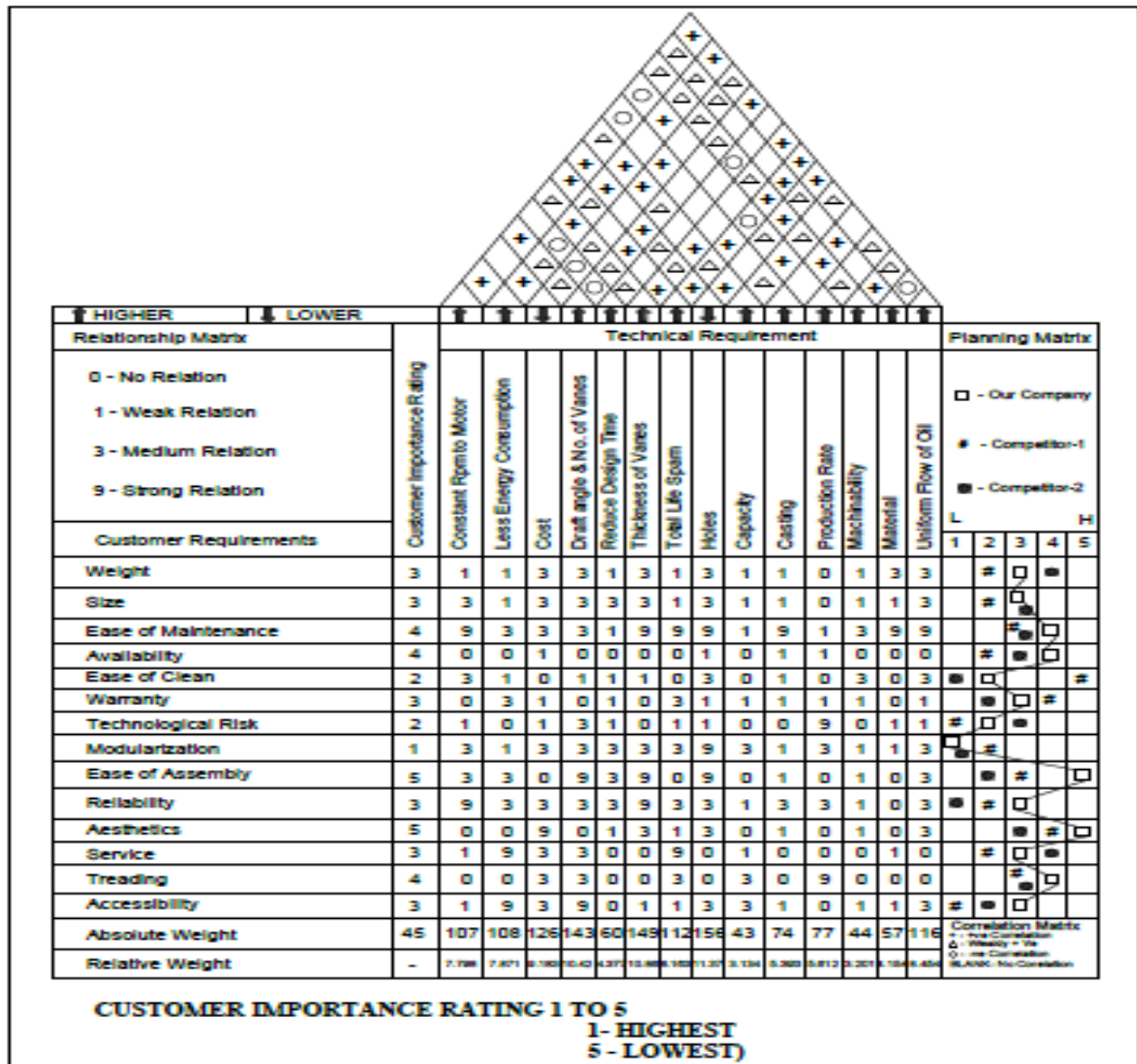


Fig. 2 House of quality matrix for an Impeller

#### 4. RESULT

In the above figure of HoQ matrix, the last step in QFD methodology is to prioritize the parameters which satisfy customer's prospects successfully. To manage this, relationship weights are multiplied by customer importance ratings. The final weights of each technical requirement is given in the above figure, which conclude the eight most important parameters which are consider to adaptation for improvement in design, these parameter are, " Regulate uniform flow of oil through impeller vanes, Holes, Thickness of vanes, Draft angle& no. of vanes, Constant RPM to motor, Cost, Total life span, Less energy consumption."

This total "Eight" results helps to improve the design & quality of the part an impeller.

#### 5. CONCLUSION

QFD is a method to translate customer needs and requirements into the quality characteristics in order to improve quality for an existing product to develop a new product that satisfy the customers. The house of quality interprets the voice of the customer into design requirements that meet specific target values and matches that against how an organization will meet those needs. In this, WHAT's i.e. customer needs are collected and processed through the open market survey. However, the

HOW's i.e. technical needs are collected by the experts' advice. Target values are connected to the house of quality. The relationship matrix is done, and the "HoQ" matrix is analyzed. Customer requirements are recorded in the rows of HoQ matrix and the design characteristics are placed in the columns of matrix. vacant row in the relation matrix identify the unmet customer expectation and vacant columns identify the mechanisms that meet no customer need. From this analysis, we conclude the eight most important parameters that are considered to modification for development in design. These parameters are, "Regulate uniform flow of oil through impeller vanes, Holes, Thickness of vanes, Draft angle& no. of vanes, Constant RPM to motor, Cost, Total life span, Less energy consumption."

On the developing upon "Eight" important engineering characteristics, we get a design of Impeller that will meet the expectations of customers.

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# Risk Assessment for Educational Institute as Per ISO 9001: 2015

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**Abstract:** The aim of this paper is to identify risk, develop the risk based thinking as per ISO 9001:2015. This paper proposes introduction of risk, its assessment and evaluates it. Also includes terms and terminology regarding risk assessment as per ISO 9001:2015. This paper gives basic knowledge of “How to assess risk in any organization?” as part of quality management system. The paper used Failure Mode and Effect analysis method for assessment of risk in an educational institute. This paper gives to introduction to risk assessment and FMEA.

**Keywords:** Risk, Risk Management, Educational Institute, ISO 9001:2015, FMEA.

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## 1. INTRODUCTION

The beginning of modern quality management systems aiming at the systematic improvement of quality and preventive actions striving at avoidance of mistakes may be considered to be individual methods, and later systems, initiated by industry producers targeted at reducing the defectiveness of produced goods. The aim of this paper is to indicate a trend of continuous adjustment of the ISO 9001 quality management system to market requirements and users' needs, with special inclusion of the need for risk assessment in organization management.

Several outer factors playing a role in the continuous improvement of the processes are new trends of the International Organization for Standardization. In September 2015 there was an update of the ISO /DIS 9001:2015 Quality management system – Requirements. Every organization implementing the quality management system based on this International Standard shall address risks and opportunities associated with its context and objectives. **A new element risk-based thinking in the procedural approach has the goal of achieving improved results and preventing negative effects.** Management of the processes can be achieved using the PDCA cycle.

The FMEA method (ČSJ, 2008) is the one used particularly in the pre-production phases regarding the preventive removal of possible defects and errors. This method enhances identification of the most critical and most probable errors in the product or in the process. This article depicts the FMEA-process. FMEA-Process investigates all potential defects of the process of production and assembling and their causes and determines necessary remedies such as, for instance, those applied during construction of FMEA. The working team is managed by the employee of the particular production department,

department of technical preparation of the production, quality assurance department or department of the industrial engineering. The method QAM – Quality Assurance Matrix - is a method used by the company BOSCH. This method has to quantify the level of the periodic quality provision of the production processes as well as verify the reliability of the existing controlling means in the process operations (BELU, 2012). Comparing to the FMEA, it can be applicable in already implemented production.

## 2. WHAT IS MEANT BY RISK?

Risk has two components. The first component is the consequences of an event when it occurs. The consequences can take on many forms including financial loss or in the worst case bodily injury. The second component of risk is the probability of the event occurring. Consequently one can reduce the risk of a particular event by taking steps to mitigate the consequences when the event occurs or to reduce the probability of the event.

According to ISO 9001, the risk is the “effect of uncertainty on an expected result” and an effect is a positive or negative deviation from what is expected. – Risk IN ISO 9001:2015, July 2014, ISO/TC 176/SC2.

Risk can be defined by two parameters, severity (This is the seriousness of harm) & probability (This is the probability that the harm will occur). The risk is the potential of gaining or losing something of value. Values (such as physical health, social status, emotional well-being, or financial wealth) can be gained or lost when taking risk resulting from a given action or inaction, foreseen or unforeseen. Risk can also be defined as the intentional interaction with uncertainty. Uncertainty is a potential, unpredictable, and uncontrollable outcome; the risk is a consequence of action taken in spite of uncertainty. According to Economics

Times, Risk implies future uncertainty about deviation from expected earnings or expected outcome. Risk measures the uncertainty that an investor is willing to take to realize again from an investment.

### 3. WHY IS RISK MANAGEMENT REQUIRED IN AN ORGANIZATION?

- The purpose of risk management is to identify potential problems before they occur so that risk-handling activities may be planned and invoked as needed across the life of the product or project to mitigate adverse impacts on achieving objectives.
- Risk management is a continuous, forward-looking process that is an important part of the business and technical management processes.
- Risk management should address issues that could endanger the achievement of critical objectives. A continuous risk management approach is applied to effectively anticipate and mitigate the risks that have a critical impact on the project.
- Effective risk management includes early and aggressive risk identification through the collaboration and involvement of relevant stakeholders.

- Strong leadership across all relevant stakeholders is needed to establish an environment for the free and open disclosure and discussion of risk.
- The another purpose of risk management is to:
  - 1) Identify possible risks;
  - 2) Reduce or Allocate risks;
  - 3) Provide rational basis for better decision making in regards to all risks and
  - 4) Plan to overcome from risk.
- The risk is the main cause of uncertainty in any organization. Thus, companies increasingly focus more on identifying risks and managing them before they even affect the business. The ability to manage risk will help companies act more confidently on future business decisions.

### 4. TERMS AND TERMINOLOGY RELATED TO RISK

Following are the terms and terminology related to risk shown in below Table 1;

**TABLE 1:- Terms & Terminology**

Sr. No.	Terms and Terminology	Definitions and Meaning
1	Risk	The combination of the probability of an event and its consequences. The risk is inherent in all types of undertaking and may carry the potential for benefit or be a threat to success. The opportunities, uncertainties, threats, or barriers to which MCCCCD must respond in order to achieve its objectives.
2	Hazard	A hazard is an act or phenomenon posing potential harm to some person (s) or thing (s), i.e., a source of harm, and its potential consequences. Hazards need to be identified and considered in projects lifecycle analyses since they could pose threats and could lead to project failures.
3	Reliability	Reliability of a system or a component is defined as the system or component ability to fulfil its design functions under designated operating or environmental conditions for a specified time period. Reliability is, therefore, the occurrence probability of the complementary event to failure as provided in the expression; Reliability= 1 – Failure Probability
4	Event Consequences	Event consequences can be defined as the degree of damage or loss from some failure. A failure could cause economic damage, environmental damage, injury or loss of human life, or other possible events. Consequences need to be quantified using relative or absolute measures for various consequence types to facilitate risk analysis.
5	Performance	The performance of a system or component can be defined as its ability to meet functional requirements. The performance of an item can be described by various elements including such items as speed, power, reliability, capability, efficiency, and maintainability. The design and operation of the product or system influence performance.
6	Risk-based Technology	Risk-based technologies (RBT) are methods or tools and processes used to assess and manage the risks of a component or system. RBT methods can be classified into risk management that includes risk assessment/risk analysis and risk control using failure prevention and consequence mitigation, and risk communication

Sr. No.	Terms and Terminology	Definitions and Meaning
7	Safety	Safety can be defined as the judgment of risk acceptability for the system. Safety is a relative term. Different people are willing to accept different risks as demonstrated by such factors as Location, Method or system types, Occupation, Life style
8	Risk Identification	The qualitative determination of risks that are material; i.e., that potentially can impact the achievement of our objectives
9	Risk Acceptance	No action is taken to affect risk likelihood or impact
10	Risk Analysis	Identifying, describing and estimating risks, and developing a risk profile.
11	Risk Assessment	Determining the impact of an identified risk on the organization. Risks are assessed on an inherent and residual basis.
12	Risk Assessment Tools	Instruments designed to assist employees in assessing and evaluating risks when making decisions.
13	Risk Control	A synonym for loss control in traditional risk management. The technique of minimizing the frequency or severity of losses with training, safety, and security measures.
14	Risk Description	To display the identified risks in a structured format, for example, by using a table.
15	Risk Estimation	The use of a tool or system (quantitative or qualitative) to determine the probability of occurrence and consequences of risks.
16	Risk Evaluation	Comparing the results of Risk Estimation to established criteria for the purpose of determining the significance of risks and whether to accept them or treat them (see also Risk Mitigation and Avoidance).
17	Risk mitigation	Actions which reduce a risk or its consequences
18	Risk Portfolio	A list of risks identified and evaluated by an organization (also called Risk Register) that represent our portfolio of risks at a certain time.
19	Risk Prioritization	The ranking of material risks on an appropriate scale, such as frequency and/or severity (see also Risk Mapping).
20	Risk Reduction	The action is taken to reduce risk likelihood or impact, or both. Measures to reduce the frequency or severity of losses. May include engineering, fire protection, safety inspections, or claims management.
21	Risk Response	Management selects risk responses-avoiding, accepting, reducing or sharing risk-developing a set of actions to align risks with the entity's risk tolerances and risk appetite
22	Risk Reporting	Publishing information on risks to internal or external stakeholders.
23	Risk Sharing	Reducing risk likelihood or impact by transferring or otherwise sharing a portion of the risk.
24	Risk Strategies	Possible responses to risk situations such as Avoidance, Acceptance, Sharing, and Reduction.
25	Risk Tolerance	The acceptable variation relative to the achievement of an objective.
26	Risk Treatment	The process of selecting and implementing measures to modify the risk.

## 5. VARIOUS METHODS OF RISK ANALYSIS

Risk analysis can be qualitative or quantitative. Qualitative risk analysis uses words or colors to identify and evaluate risks or presents a written description of the risk,

and Quantitative risk analysis (QRA) calculates numerical probabilities over the possible consequences. The below figure 1 represent future classification of risk analysis methods;

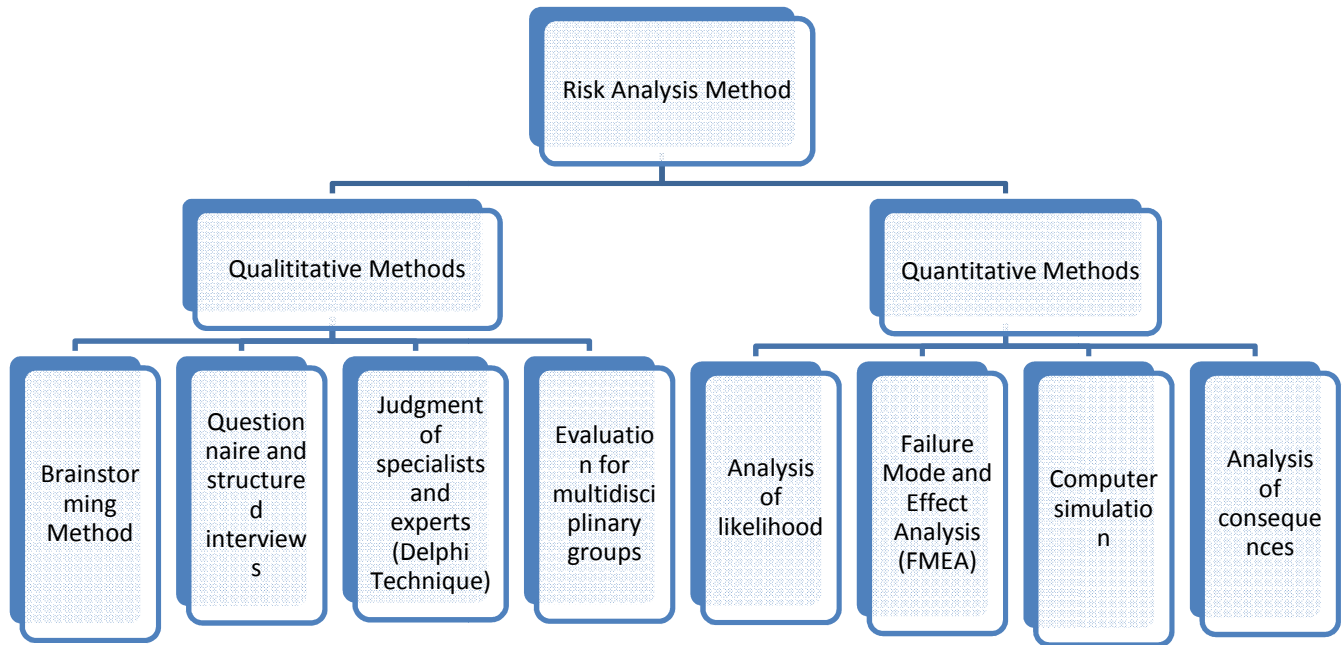


Fig. 1.

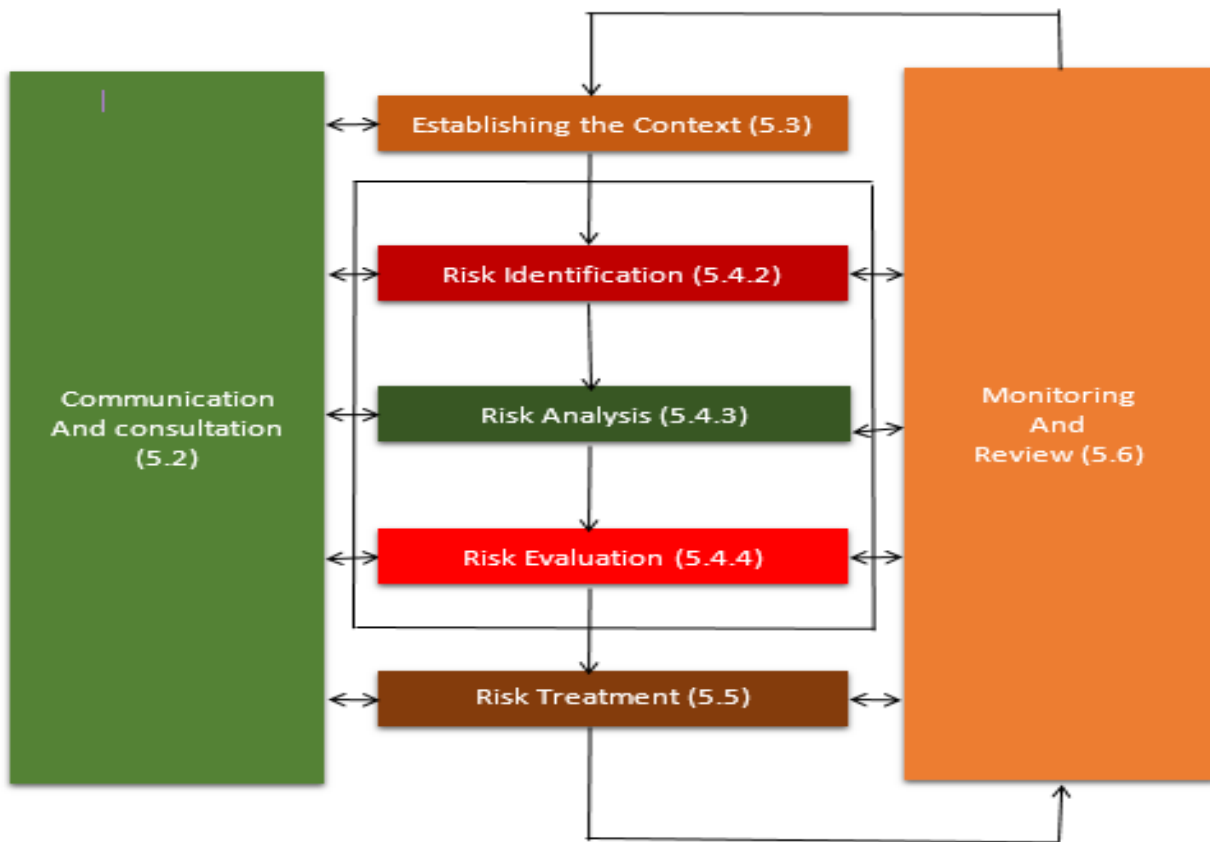


Figure 2 Risk Assessment

## 6. FAILURE MODE AND EFFECT ANALYSIS (FMEA)

Now we discuss Failure Mode and Effect Analysis (FMEA), The FMEA method is the one used particularly in the pre-planning phases regarding the preventive removal of possible defects and errors. This method enhances identification of the most critical and most probable errors in the product or in the process. FMEA-Process investigates all potential defects of the process of production and assembling and their causes and determines necessary remedies such as, for instance, those applied during construction of FMEA. The working team is managed by the employee of the particular production department, department of technical preparation of the production, quality assurance department or department of the industrial engineering.

**Failure Modes:** - A failure mode is a way in which a specific process or product fails. It is a description of features that can be negatively affected by a process step or component.

**Failure Effects:** - Failure effects are the impact on the end user or regulatory requirements. They are what the end user might experience or notice as a result of the failure mode. The effect is the outcome of the occurrence of the failure mode on the system.

### Methodology of Risk Assessment

The following figure 2 shows, steps of risk assessment as per ISO 9001:2015 clauses.

Risk analysis process to comprehend the nature of risk and to determine the level of risk. In many cases Qualification approach to Quantifying. The identified attributes of risk are Probability, Severity and Detection. The rating is given

to each attribute in the scale of 1-5. Each rating has different significant meaning with respect to attributes of risk.

### Severity Criteria for FMEA

In general, severity assesses how serious the effects would be should the potential risk occur. In the example of a manufacturing process for a drug substance, the severity score is rated against the impact of the effect caused by the failure mode on the batch quality. A nonlinear scoring scale can be applied to augment the effect of the severity criteria as shown in Table 2 below;

**TABLE 2:- Severity: The Severity of Injury [hazard]**

Value	Description	Criteria
1	Irrelevant	No impact to product quality and process robustness
2	Slight	No impact to product quality
3	Important	Noticeable impact on product quality, but can be recovered by reprocessing
4	Critical	Definite impact to product quality that may require rework
5	Disastrous	Batch failure, not recoverable by rework

### The probability of Occurrence Criteria for FMEA.

In general, the probability of occurrence evaluates the frequency that potential risk(s) will occur for a given system or situation. The probability score is rated against the probability that the effect occurs as a result of a failure mode. A linear scoring scale to the probability of occurrence of failure modes associated with the educational process as shown in Table 3 below;

**TABLE 3:- Probability: The likelihood that the “event” will occur [aspect/impact]**

Value	Description	Criteria
1	An unlikely probability of occurrence	Failure has <b>never</b> been seen in any relevant lab experiments, or scale-up batches yet but it is theoretically possible.
2	A remote probability of occurrence	Failure only is seen <b>once or twice</b> in relevant lab experiments, never in scale-up batches
3	An occasional probability of occurrence	Failure potential has been noted in <b>several</b> relevant lab experiments, or at scale-up. If procedures are followed the failure potential is minimal
4	A moderate probability of occurrence	Failure potential has been noted in several relevant lab experiments, or at scale-up, in process control maybe required to avoid failure.
5	A high probability of occurrence	Failure potential has been noted in several relevant lab experiments, or at scale-up, an active non-standard feedback control loop may be required



### Detectability Criteria for FMEA

In general, detectability is the probability of the failure being detected before the impact of the failure to the system or process being evaluated is detected. The detectability

score is rated against the ability to detect the effect of the failure mode or the ability to detect the failure mode itself. A linear scoring scale to the detectability criteria in a FMEA for an educational process shown in Table 4;

**TABLE 4: Detectability: The Mechanism for detecting risk.**

Value	Description	Criteria
1	High degree of detectability	A: Validated automatic detection system that is a direct measure of failure. B: Two or more manual operated validated detection systems, direct or indirect. (e.g. Control range and IPC)
2	Good detectability	A single manually operated validated detection system that is a direct measure of failure. (e.g. IPC of failure, validated PAT)
3	Likely to detect	A single manually operated validated detection system that is not a direct measure of failure. (e.g. PAT measurements or IPC's not directly linked to failure)
4	Fair detectability	Non-validated (manual or automated) detection. (e.g. visual level check, visual inspection of vessels)
5	Low or no detectability	No ability to detect the failure

### Risk score matrix

The composite risk score for each unit operation step is the product of its three individual component ratings: severity, probability, and detectability. This composite risk is called a risk priority number (RPN).

### RPN = Severity x Probability x Detection

The RPN number is not absolute and should be considered in context with other factors that influence the product risk outside the scope of this evaluation. The RPN provides a relative priority for taking action - the bigger the RPN, the more important to address the corresponding failure being assessed.

### Case Study:- Risk assessment for Educational Institute

Risk assessment means identification, analysis and evaluation of the risk. Risk evaluation means the comparison of the results of the risk analysis with the

risk criteria. The method of FMEA Process determines in the analysis of the defects the probability of the occurrence of defects, the significance of the defects for the customer as well as detection of the defect arisen. As part of these assessment categories, there is an assessment range 1-5. On the basis of the sum of these categories, the risk number so-called RPN is calculated and it could be in the value of 1-125. The specialized literature (ČSJ, 2008) suggests determining such value defined by the customer as critical RPN. In the case studies, the risk value was determined as the value of 60 which calculates an average of maximum RPN. This case study was done in the engineering college at Nagpur. The Failure Mode and Effect Analysis (FMEA) did in the point of view of organizational by introducing the external and internal issue of educational organization. The rating of risk is given by brainstorming with management personnel and senior people of educational institute. The significant column gives information about risk which important or not on base on risk criteria. The rating and significant of risk is shown in Table 5;

**TABLE 5:- RISK ASSESSMENT OF EDUCATIONAL INSTITUTE ORGANIZATIONAL LEVEL ASSESSMENT**

Sr.no	Activity/Area /Process	Risk	Severity	Occurrences	Detectability	RPN	Significant or Not? (Significant for RPN>60)
1	External: Political/Government	Changing of education policy & Influence of	4	2	3	24	NS

Sr.no	Activity/Area /Process	Risk	Severity	Occurrences	Detectability	RPN	Significant or Not? (Significant for RPN>60)
	Risk	local politician					
2	External: Market Competition	Increasing colleges	3	3	2	18	NS
3	External: Customer Related Risk	Demand of Industry is changing regarding skills of employee	5	3	2	30	NS
4	External: Financial Risk	Late payment of scholarship or increasing fees	4	4	2	32	NS
5	External: Weather Risks	Natural Disaster such as Heavy Rain, Earth-quake etc.	3	3	2	18	NS
6	External: Man-Power related	Lack of Companion People or Senior level professor drop out	5	2	3	30	NS
7	Internal: Teaching Failure	Syllabus not complete, Teaching not complete, Assignment/practices not carried out	5	4	2	40	NS
8	Internal: Examination	Schedule not displayed, Schedule too compact or spread over, Exam paper out of syllabus, Timing of exam is odd	4	2	2	16	NS
9	Internal: Library	Books are not available or in good condition, staff are not available	5	4	3	60	YS
10	Internal: Facility	Central Store timing, availability of items are not proper, Xerox facility is not available	3	4	4	48	NS
11	Internal: Canteen	Serving of Junk Food, Health and hygiene issues,	5	4	3	60	YS
12	Internal: Parking	Arrangements and Security of Vehicles, Vehicles may be theft	4	3	2	24	NS
13	Internal: Admission Department	Admission Process is difficult	4	2	3	24	NS
14	Internal: Finance Department	Staff are not available, Not polite to students	4	3	4	48	NS
15	Internal: Hostel	Cleaning, Ragging activity, or another facility	5	3	4	60	YS

Sr.no	Activity/Area /Process	Risk	Severity	Occurrences	Detectability	RPN	Significant or Not? (Significant for RPN>60)
16	Internal: Safety & Security	Security of girls student and staff	5	3	4	60	YS

As part of the case studies the method FMEA was used for risk identification and assessment for the educational process. By means of the method, FMEA 4 defects or nonconformity were assessed as risky ones, meaning non-acceptable. We suggest corrective action for mitigation of risk. For risk related to the library, we will minimize risk by providing book bang & procure the new books. The risk canteen will minimize by providing regular audit of foodstuff by management personnel and also give the option of healthy food such as juice, shake and fruit plate etc. Also, increase awareness of healthy habits among students. By providing proper cleaning schedule and making anti-ragging committee member from fresher's student. For the safety of girls, we will provide cameras with a security guard on the premises of educational institute and increase awareness among them. This will action taken to prevent risk to happen.

## 7. CONCLUSION

As part of the risk-based thinking in the processes influencing the customer, it is necessary to set up a well-functioning system of the actions to address risk in the organisation. This article has assessed method that is used for defining and evaluation of the risks in the process. The objective was to find out whether these methods are usable for the actions to address the risk that resulted from the new requirements of the ISO /FDIS 9001:2015 - Quality management system – Requirements. On the basis of the case studies, it was found out that the method FMEA Process is a complex tool for identification, analysis and evaluation of risks in the education process. It is not sufficient to use the tool FMEA Process solely according to the instructions in the specialized literature; it is necessary to set up the in-house procedure for utilisation of the FMEA tool as a tool for prevention of any errors. This is evident particularly in the subjective procedure during the risk

analysis. It has been evaluated that the FMEA Process method is a more exact tool for identification of risks in the educational process from the perspective of recognizing and describing risks

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# Product Improvement using Integrated Target Costing and Quality Function Deployment

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**Abstract:** The aim of this paper proposes an integrated approach of Quality Function Deployment (QFD) and Target Costing (TC). This integrated approach helps to achieve best optimum solution in an existing product in a systematic way. In QFD, Customer Requirements (CRs) were systematically identified and translate in the terms of Engineering Characteristics (ECs). The QFD is developed with the help of Analytical Network Process (ANP). It helps to calculate the pairwise comparison matrix between CRs and ECs and inner dependencies among them and check the consistency ratio of each pairwise comparison matrixes. Identification of customer preferences and satisfaction levels can be achieved by QFD analysis, and target goals for product quality and costs using TC method. TC is an important tool for sustaining manufacturers' overall efforts to remain cost competitive while meeting standards and specifications demanded by customers. The application of TC use in the product improvement process that can maintain balance between quality and cost of product and it can be proved a key system for the growth and profitability of a company. A framework is validated with a case study conducted in an Indian manufacturing industry is presented in this paper. On successful deployment of QFD-TC approach the manufacturing costs incurred have been reduced by incorporating changes in the part material. The outcomes of this study have been considered for further implementation in the case organization which indicated the practicality of the study.

**Keywords:** Product improvement, Quality Function Deployment, Target Costing, Analytical network process

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## 1. INTRODUCTION

In recent times, due to increased global competition, manufacturers face ever challenging conditions in the market. This keen challenge forces manufacturers to focus on innovation for maintaining the desired penetration in the market. To carry on in such an intense competitive environment, manufacturers must develop products at competitive costs that deliver quality and functionality and accomplish customer's desires. New product needs to be manufactured at the most economical cost to get good penetration in the market and earn good profit. The need of the hour is to introduce such features in the product which are highly rated by customers that too at the most economical way. To achieve above object integration of Quality Function Deployment (QFD) and Target Costing (TC) helps to identify the customer requirement and find best optimum solutions.

To meet this aim academicians and practitioners has suggested that for a company to remain competitive, it has to work with product designers to improve overall product performance is required to consider product cost throughout the design stage.

Target Costing (TC) is a widelyused technique for cost management during product development (Cooper and Slagmulder, 1997). TC can be implemented more effectively with the support of QFD analysis. It helps to identify the customer's requirements in the initial phase of product development and focuses on these engineering characteristics which are highly rated by the customers and

helps them to reduce the engineering characteristics (Sharma, 2012). The outcome of QFD helps in the TC process to find an alternative solution to provide the best features in product and provides most optimal substitute of its constituent. Integration of QFD and TC provides an optimum solution and helps in integrating customer requirements, technical specification and cost information during the product design phase. It helps in reducing the cost of the product by eliminating the non value added activities and functions. In the present study, a popular decision making tool is Analytic Network Process (ANP) to incorporate with QFD. The reason behind the use of the ANP is because there are inner dependence among Customer Requirements (CRs) and Engineering Characteristics (ECs) (Saaty 1996). ANP is a good methodology to consider such inner dependencies in the QFD analysis.

The rest of this paper is organized as follows. After introduction section, in section 2, reviews the literature on integration of QFD-TC in product development. Next section 3, Developed the framework of QFD-TC methodology. Section 4, a case study is demonstrated and develop QFD-TC model for considerable product. Section 5, is shows the outcome of this paper and section 6, the conclusion is presented.

## 2. LITERATURE REVIEW OF INTEGRATION OF QFD-TC IN PRODUCT IMPROVEMENT

Effective product design requires inter-functional and close relationship between various managerial functions.

Determination of customer preferences and satisfaction levels can be achieved by QFD analysis, and target goals for quality and costs using TC method (Ewert and Ernst, 1999). QFD and TC must be treated as a multi-functional team work bringing customers, engineers, designers, accountants and sales people together (Sharma, 2012). It is best implemented by a team that aims to develop the right quality and functionality with right pricing. Gandhinathan et al. (2004) discussed the effect of as Quality Function Deployment (QFD) and Value Engineering (VE) on target costing and explores the way in which these tools assist in achieving the target cost. Jariri and Zegordi(2006) applied a model which used QFD data and provided the starting solution for the platform design team in an automaker company located in the Middle East for the target costing process. The model essentially optimizes customer satisfaction subject to target cost. Shun and Kosuke(2006) presented a system design methodology that integrated perception-based concept evaluation and TC of complex and large-scale systems by using QFD matrices simultaneously for both requirements and structure in order to allocate the worth and target cost of the modules in a

system in order to satisfy both customer and financial requirements. Zengin and Ada (2010) presented the methodology of product development in an assembly oriented company to explore the role of target costing in managing product costs while promoting quality specifications that meets customer requirements. Durga Prasad et al. (2014) discussed that the effective cost management during the conceptual design phase of a product is essential to develop a product with minimum cost and desired quality. The integration of the methodologies of QFD and TC could be applied to the continuous improvement of any product during product development. Customer requirements, product functions and cost are three important elements of the TC process. While maximizing customer satisfaction is the philosophy of QFD and it directly affects sales and therefore maintains the current market and provides a strong basis for increasing market share. Integration of target costing and QFD process (QFD-TC process) is a good cost management strategy for an organization. In Figure 1, QFD-TC process is illustrated (Ellram1999).

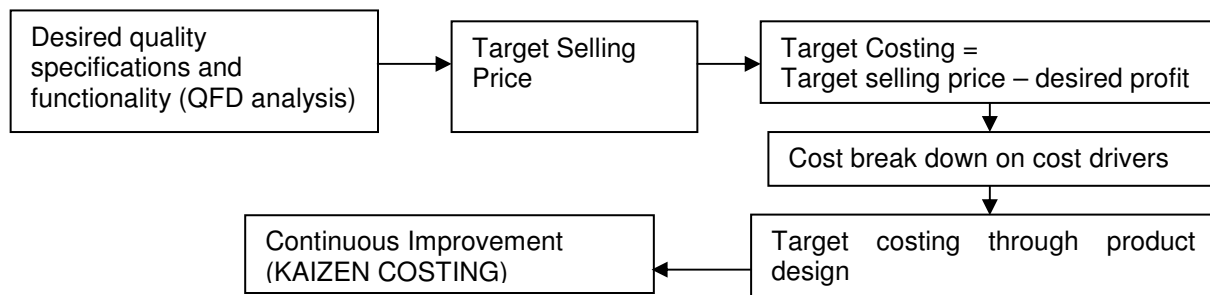


Fig. 1. QFD-TC process

### 3. THE PRAPOSED METHODOLOGY

The methodology followed during this study is shown in Figure 2.

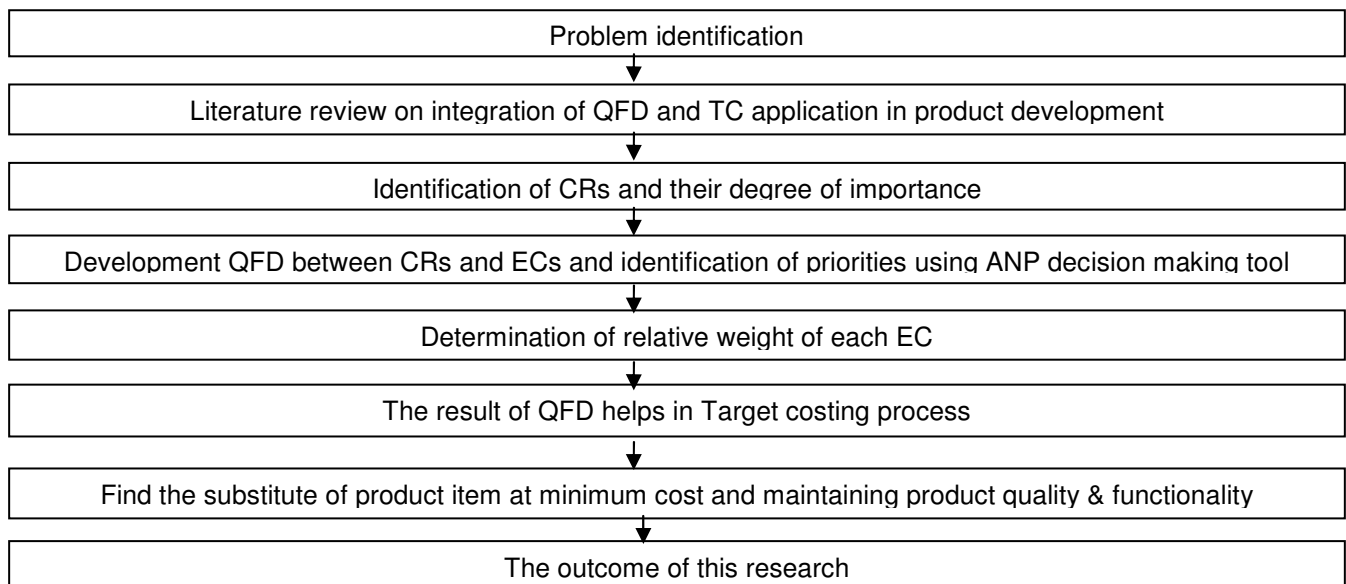


Fig. 2.

## 4. CASE STUDY

In this section, a case study is presented illustrate the application of integrated QFD-TC method in product development phase.

### 4.1 About case company

The research is carried out in a small manufacturing company that manufactures various types' stainless steel submersible pumps. The XYZ Company manufactures product parts as well as assembles the product located at Jodhpur (Rajasthan) India. We conducted an intensive investigation marketing research on a submersible pump. Found that product is not cost competitive in the market. To overcome on this problem an integration of QFD-TC method is proposed for this case organization.

### 4.2 Construction of QFD

QFD is a method of structured product development. It enables a development team to specify clearly the customer's wants and needs, and then evaluates each proposed product systematically in terms of its impact on meeting those needs (Hauser and Clausing, 1988). A marketing survey was conducted for a product and many discussions were held with the manufacturer of submersible pump and its end users. The CRs were identified and there degree of importance for this product on likert scale 1 to 9 (1 means extremely disagree – 9 means extremely agree). After that ECs were identified according to CRs. make a relationship matrix is called house of quality and construct the QFD with help of ANP as shown in figure 3. The ANP helps in QFD matrix to identify the overall priorities of ECs with the contribution of inner dependence and interrelationship matrix of CRs and ECs.

The results show that the most important engineering parameter is the Strainer with a relative value of 13.887, followed by NRV, impeller, Pump Shaft, Bearing & its components, Suction Case, diffuser bowl and diffuser blade.

### 4.3 Integration of QFD and TC of product under consideration

TC is a comprehensive cost management method to identify the target cost of the product. It mainly focuses on market conditions, customers' expectation in terms of product quality, functionality and cost (Ansari, et al. 1997). It is recognized as a tool, to control costs and manufacture product ensuring that the product provides value to the customer and at the same time create a desirable profit margin for the company. These objectives are achieved by disciplining the product development process and identifying the cost at which the product must be

manufactured, if it is to achieve its desired profit margin when sold at its target selling price. A systematic approach of TC has been applied to a stainless steel submersible pump and main challenge were to suggest and proposed a model to be cost competitive without compromising with the product quality and functionality while meeting CRs. The outcome of QFD helps the TC process to find substitute of product items at similar cost and helps to achieve the target cost. TC integrates the customer's needs, product specification and cost information. To achieve this object QFD has been integrated with the TC process for the stainless steel submersible pump being manufactured by XYZ Company with an intention to find the best optimum solution to achieve product target cost.

Compared with its competitors as shown in Figure 3, The Company has problems in the area of easy to install, serviceability, consistent output and power/current consumption. Improvements will be therefore begin by the designing a new Non Return Valve (NRV) and Impeller for the pump. The NRV provides easy to install with a consistent service of product and impeller gives low power/current consumption, consistent output and long life and trouble free operation of pump. So, design team focus on these product parts to find out of substitutes or revised the design of product parts and improves product function significantly manners.

### 4.4 Target costing through product design

Using customer input to select the items that should be improved and reduce cost. Manufacturers are required to focus on the design process and lower cost while maintaining product desired quality and functionality. After considering QFD analysis and main cost drivers, focuses on those ECs or product items which are highly demanded by the customers. Designers focus on those product items for their cost reduction by considering the three ECs for improving these items' quality which are highly demanded such as strainer, Non Return Valve (NRV) and Impeller are shown below.

1. The company already uses a better kind of material stainless steel grade AISI 318 for the strainer. The function of strainer is to prevent particles over a certain size from entering the pump. It is corrosive resistance, longer useful life, reasonable cost and highly demanded by the customers. So, the cost of strainer does not affect the total product cost.
2. The function of NRV is to prevent back flow in connection with pump stoppage and also reduces water hammering. At present company manufactures stainless steel NRV. It is highly correlated to easy to install and compared to the competitors the company has problem in the area of installation. To solve this

problem designer and engineer focus on new designs for submersible pump to replace stainless steel NRV (fabricate) with an investment cast NRV one. The advantages of stainless steel NRV are less weight, lower manufacturing cost. The disadvantage is difficult to install pumps in deep well. The advantages of investment cast NRV are easy to install a submersible pump in deep wells, highly precise material, and long life support of the pump. Disadvantages are slightly higher weight, expensive because they are imported.

3. The function of Impeller is to take power from the rotating shaft and accelerates the fluid. In the existing pump, the company uses stainless steel sheets to manufacture impellers. Notify the designer replace stainless steel by engineering plastic Polycarbonate (Noryl). The advantages of polycarbonate (Noryl) are easy manufacturing process (Injection molding method); reduce power consumption, excellent dimensional stability, corrosive resistant to salt water, consistent output and more long life usually than stainless steel.

The following above ECs were considered and Comparative cost analysis of existing and new design based as shown in table I.

**TABLE I: Comparative cost analysis of existing and new design based**

Total manufacturing cost	Existing cost	Current cost
Suction case	930	930
Strainer	385	385
Pump shaft	685	685
Diffuser blade	7000	7000
Impeller	5050	180
Diffuser casing (bowl)	11210	11210
Rubber bearings & its components	1250	1250
Non return valve (NRV)	1630	1630
Labor cost	526	526
Manufacturing overheads	610	610
Total cost	29276	24406

The optimum product was designed by keeping the cost, quality and functionality. In Table I, the new design of the product resulted in reduction of cost of production from • 24686.9 to • 24631 per pump, which is less than the target cost • 24686.9 per pump.

## 5. RESULT

The new design of the product resulted in reduction of cost of production from • 24686.9 to • 24631 per pump. It results in considerable cost reduction for the product under consideration. The following changes are proposed: The stainless steel impeller is replaced by the proposed Noryl impeller because it improves the main function of the pump. The advantages over stainless steel impeller are easy manufacturability, light weight, less cost, reduced power consumption, corrosive resistance to salty water, consistent output and useful long life. The stainless steel Non Return Valve (NRV) is replaced by the proposed investment casted NRV, which results in saving on assembling, machining time and reduces material waste. Further advantage over the stainless steel NRV are easy to install, highly precise material, long life support.

## 6. CONCLUSION

In today's market, the success of company depends upon its capability to meet the customers' requirement and expectations and that too at the most competitive price. In this paper integrated approach of QFD and TC has been used to improve the existing product design. Implementing QFD - TC process basically deals with identifying CRs and modifying the product to meet those requirements at the identified target cost. TC is a cost management tool usually used to give cost advantages to the company in the competitive market. TC integrated with QFD helps to identify the CRs in the initial phase of product design which helps the TC to choose the best alternative of ECs to reduce the cost of product and improve quality. Managing product costs during product design is not enough, continuous cost reduction activities should continue in the production stage to achieve the overall product target cost. In this paper, the QFD has been used to identify CRs and transformed in the terms of ECs. The QFD was developed with the help of ANP. It helps to calculate the pairwise comparison matrix between CRs and ECs and inner dependencies among them. The overall weights assigned to each EC were calculated and those ECs which had higher weight were the focus of the study. The outcome of QFD use as in input to the TC method to find the substitute of product parts which have higher ratings, cost calculations were carried out and the actions were derived to achieve the target cost of the product.

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# Quality Planning of New Product in Garment Industry using QFD and AHP Methods

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**Abstract:** The objective of this paper is to identify customer requirement parameters for a product in garment industry; to identify product requirements for a particular product; and to determine the absolute importance values of product requirements for the purpose of launching of a new product. The quality function deployment (QFD) and analytical hierarchy process (AHP) methods are used in this research. A survey is also conducted to collect the data for prioritization of customer requirement parameters. The results the study shows that still today the choice of a middle class person is buy more reliable product. The study is limited to Malwa region only. Further this type of study can be done to some other area/region/state/country.

**Keywords:** New Product Development, Quality Function Deployment, Quality Control, Analytical Hierarchy Process.

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## 1. INTRODUCTION

Quality improvement is the basic concern in any Industry for which Quality Function Deployment (QFD) can be use as a quality tool that helps to translate the Consumers voice or need into products specifications which are helpful in satisfying their needs. It is important to understand how it works, to emphasize its pros and cons and to confer its sensible application [Akao, Y., (1990).]. it is the oldest known method or concept for developing new product .QFD may be used as a communication tool between customer and company also it reduce the gap between consumer and industry [Akao, Y., (1997)]. It provides an supportive system for the design and manufacturing and it can significantly develop the effectiveness as problems during production phases can be resolve in design phase [Bernal L et al., 2009]. It is very helpful is getting needs of customer during design phases therefore it is expected that the finished product will be better designed to satisfy the consumer needs. [Bhanot, S., 2013].

This study is done with the basic thought to provide a solution for garment industries for increasing their product quality without making many changes in their existing setups. The reason for selecting garment industries is that the Malwa region is even after so many years is not able to establish itself as stable garment industrial region. Most of the units working in this region are of small and medium size and are struggling to run in a state of profit .During the complete master course, it has been felt that for the development for the Malwa region some work is required to be done for garment industries so that the major industrial players of this region can perform in a better way. This thought of development of industries as a mechanical engineer motivated for selecting this topic as the major project.

Along with this, the main motive for taking up this study as project is to learn basic procedure of QFD in garment industry and to calculate its better effects in mathematical terms. QFD is the need of time, as it encourages every person involved in a positive way which otherwise is very hard to achieve and at the same time if the continuous improvement is not chased, it is impossible to sustain in such a competitive business environment especially for garment industries for which task is more tough [Booz et al., 1982] .

Following are the objectives of the research:

- To identify customer requirement parameters for a product in garment industry;
- To identify product requirements for a particular product;
- To determine the absolute importance values of product requirements for the purpose of launching of a new product.

This paper is organized in five sections including introduction. The second section includes literature review, followed by research methodology in third section. The section fourth deals with result and discussion. The last section five presents conclusion of the research.

## 2. LITERATURE REVIEW

This study is devoted to various aspects of garment industry, and tells about the recent researches in the field of garment industries in India and Indore. It also contains customer buying behaviour, preference and new product development process related discussion

### **2.1 Some important facts about Garment Industry in India**

In world India has second ranking among largest producer of garment after china. Cotton is the most important ingredient for the garment industry. among the largest producer of cotton India has third ranking after china and USA and as India has the world's second largest population that's why it is second largest consumer of cotton. India has the second largest population in the world so garment industries can achieve faster growth than any other country [Chan, 2002]. The primary potential of this industry is that it uses natural fibres such as cotton, jute, silk and wool for production of wide range of products. It also uses synthetic fibres such as polyester, viscose, nylon and acrylic. The Indian textile industry is growing day by day because government also provides support and facilities and makes policies which are useful for the garment industry [Clausing, 1994].

### **2.2 Background of Garment Industries in Indore Region**

The foreign market warmly welcomes the product made by manufacturer in Indore. Manufacturers make the product and supply it by different supply and marketing channels in U.K., France, Other EU Countries, and Middle East etc. In Indore city there are so many textile industries so it makes easier to produce garments. The garment industries also established at different parts of Maharashtra and Gujarat [Cohen, 1995]. The convenient garment industry taking place with a vision to supply dresses to the Royal families of the Holkar State. The ready-to-wear garment industry in this period fashioned new style and designs adding together importance to the products with gold and silver stitching and other artwork with appropriate stuff, the best quality of the raw materials and skill used during those days made the dresses and outstanding work of art. The skilled workers were encouraged for good work and for popularizing the industry across the country. Till now there are only 10-15 garment units in Indore so there is a lot of work to be done in this field [Cooper, 2001].

### **2.3 Customer Buying Behaviour towards Garments**

Clothing is one of the basic necessities of human civilization along with food, water and shelter. The Apparel Industry reflects people's lifestyles and shows their social and economic status. The Apparel and Textile industry is India's second largest industry after the IT Industry [Crawford, 1992]. Consumer's view towards clothing can be viewed as a result that takes into account the intellectual aspects as well as changes in priorities and tastes. The connection among characteristics of both customers and brands are becoming increasingly important marketing issues, particularly with features such as greediness being a strong factor of acquiring and consuming specific types of styles and brands. Clothing is considered to be second skin of the body and interest in clothing is higher during the whole life. Today, we live in a consumer based society where consumer is known as the

king of the market. The behaviour of the customer affects the market size, brand name, fashion etc [Gonzalez, 2003].

### **2.4 Factors of Garment Buying Behaviour**

The consumer's buying behaviour mainly depends on five factors namely consumer characteristics, reference groups, store attributes, promotion and product attributes. Customer features are the customer attributes like importance, manner & brand name consciousness, faithfulness, passion etc. which varies from consumer to consumer and also have effect on apparel buying behaviour. Reference groups are the outside influences like TV programmes, magazine, consumers' favourite celebrities or stars, friends, family, other individuals etc. which controls the attire purchasing behaviour of the customers. Store attributes are the store environment and features like conveniences in the store, store services, store design etc. which controls the consumer attire purchasing behaviour. Endorsement is the various advertising technique adopted by the selling stores to draw and convince consumers. Much earlier investigation indicates that there is a main influence of promotional techniques on consumer buying behaviour. [Gurunathan and Krishnakumar, (2013); Hauser and Clausing, 1988].

### **2.5 Process of New Product Development**

For the proper growth and competing in the market the new product development is very essential. When customer requirements or need arises there is new product development. When new product is introduced on the market it follows the different types of stages, starting with a primary creation idea that is estimated, created, simulated and sent on the market [Lootsma, 1997]. These activities can also be seen as a sequence of information collection and estimation stages. Various steps of NPD are as shown below:

- **Strategy formation for new product:** this is the initial stage of the new product development which provides the link between the NPD processes to industrial aim and concentrated on concept creation and guidelines for establishing screening criteria.
- **Thought creation:** collecting new thoughts and ideas that meet company objectives.
- **Selection of ideas:** Choosing the best idea.
- **Business examination:** after choosing the best idea these are sent to the company expert for evaluation of ideas are done on the basis of profits, Return-on-investment (ROI), and sales volume.
- **Finalisation of product:** a sample sketch of idea is created in Paper and Product is finalised.

- **Investigate:** after finalisation of product, investigation of the market is important as it is suitable for the market or not.
- **Launching of product:** After proper investigation product launch in the market [Macharis, 2004]



**Fig. 1. Stages of New Product Development (NPD)**[Millet, 2002]

### 3. RESEARCH METHODOLOGY

This paper proposes the combination of Quality function deployment (QFD) and AHP. QFD and Analytical hierarchy process represent different streams of industrial engineering and therefore, are based on different kind of foundations. The chapter is devoted to the details of research methodology being adopted for implementation of concepts on an industry. The concept of QFD was originated in Japan in 1966[Mohamad, 2005], but later it gain recognition in different parts of the world, a outline of which is presented below, in past when Japanese companies falls since world war second. QFD was originated in this situation as a method for NPD [Bhuiyan (2011)].The QFD is introduced in America and Europe in 1983. The important study of America to date on QFD suggests that important part of it has been the enhancement of the product development process so that it is more efficient in the long term [Paryani, 2010; Radharamanan, 1996]. QFD methodology is used for transformation of the voice of the customer into product features and promotes it into process and production characteristics. A basic concept is the house of quality, which links a chain between the customer and production system. That means, QFD offer a planned approach in linking quality related market requirements to various manufacturing process features [Rajput, 2012].

### 3.1 Overview of Analytic Hierarchy Process (AHP)

The AHP is a multi criteria decision method, developed by T.Saaty at the Wharton School of Business after that it is used in many research fields. In AHP the decision problem required to be prepared hierarchically in relation to the main objective. After that, pair wise comparisons have to be prepared at every level of the hierarchical structure composed of criteria to assess the overall priorities of the alternatives in relation to the main goal [Ramanathan, 2001]. This can be done by use of a referential scale known as 9 point scale which is written in the square matrix form .In the nine points scale proposed originally by Saaty, the number 9 means that criterion  $i$  is extremely more important/relevant in respect to criterion  $j$  regarding the super ordinate goal. The opposite is measured by the inverse (*i.e.*  $1/9$ ) [Saaty, T.L., (1980)].This entire procedure is based on calculating the geometric mean [Saaty, T.L., (1994)]. As decision makers can be not steady because of the contradiction in their judgments, the AHP method has tools for consistence analysis. When there are number of decision makers the AHP method has tools aggregate the experts' judgments, the most absolute technique being the geometric mean [Saaty and Alexander., (1989).].

For assigning arithmetic values to the compared result, we use a pair wise evaluation scale which may be like the one shown below in Table 1

**TABLE 1: Pair wise Comparison Scale [ Shulin, 2011]**

Definition	Intensity of Importance
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9

### 3.2 The Combination of QFD-AHP Approach

In many decision making problems the approach of using QFD with Analytic Hierarchy Process (AHP) is gaining wide acceptance [Tan et al., 1998]. Combination of these two solves the decision making problem very easily. This collective approach is useful for enhancement of effectiveness of the decision making process and is also used to deal with the linguistic decisions that take place when conveying relationships and connections required in the QFD approach. Earlier uses of the QFD-AHP approach have been made in areas such as facility location problems and estimation of hardware for mobile stations [Tenday, 2013; Thakur, 2013]

## 4. DATA ANALYSIS AND DISCUSSION

Following are the major stages of research work conducted:

- Customer requirement identification and finalization;
- Product requirement identification;
- Prioritization of customer requirements;
- Interrelationship matrix formation, dictating correlation between customer requirements and product requirements;
- Evaluation of product requirements

First of all, customer requirements were investigated. From the survey of available literature, there was no research available in which QFD is applied for new product development planning, therefore investigated for the customer requirement parameters. Customer requirement parameters are obtained as the result of series of informal discussions with customers, shopkeepers and company personnel [Unger and Eppinger, 2011; Zahir, 1999]. Demographic details of discussions are presented in table.

Details of responses collected for Customer Requirement Parameters

**TABLE 2: Details of responses collected for Customer Requirement Parameter (CRP)**

Sr. No	Item	Output
1	Number of interviews	93
2	Number of responses obtained	93
3	Response Ratio	100 %

#### 4.2 Customer Requirement Parameters (CRP)

These Parameters are selected by Informal discussions form customers, shopkeepers and industry personnel which shows in Table 3

**TABLE 3: Shows the details of customer requirement parameters**

S. No	CRP	Abbreviation	Reference
1	Availability in more sizes	AMS	Informal discussions
2	More comfort	MC	Do
3	Less cost	LC	Do
4	More life	ML	Do
5	No colour change	NCC	Do
6	Good elastic behaviour of cloth	GABC	Do
7	No harm to skin	NHS	Do

8	No wobbling	NW	Do
9	Hot in winter and cold in summer	HWCS	Do
10	Less time to dry after washing	LTDAAW	Do
11	No effects of cuts	NEC	Do
12	Rain resistant	RR	Do
13	Sufficient air passing	SAP	Do
14	Availability in more colors	AMC	Do
15	Availability in more patterns	AMP	Do
16	Easy availability	EA	Do
17	No cracking in material	NCM	Do
18	Permanent stitching	PS	Do
19	Modifications to change size	MCSZ	Do

Next step was to prioritize the customer requirements using AHP. For this purpose a questionnaire based Likert scale (of 5-point type) was distributed to the customers, shopkeepers and company personnel to investigate the importance of customer requirements [Zaiml, 1998].

Around 100 response were taken after that average were taken, that shows in the Table 4

**TABLE 4: Average values of customer responses  
(No. of respondents =100)**

S. No.	Criteria	Average
1	Availability in more sizes	3.65
2	More comfort	4.01
3	Less cost	4.00
4	More life	3.88
5	No color change	3.51
6	Good elastic behavior of cloth	3.61
7	No harm to skin	3.63
8	No wobbling	3.57
9	Hot in winter and cold in summer	3.60
10	Less time to dry after washing	3.16
11	No effects of cuts	3.79
12	Rain resistant	3.34

S. No.	Criteria	Average
13	Sufficient air passing	3.40
14	Availability in more colors	3.42
15	Availability in more patterns	3.55
16	Easy availability	3.54
17	No cracking in material	3.52
18	Permanent stitching	3.35
19	Modifications to change size	3.28

After getting sufficient responses from the respondents, pair wise comparison of customer requirements was conducted, the average scores are from above table, the intensity was given by a company expert, Scale used will be Saaty's scale as shown in Table below sample of comparison.

**TABLE 5: Pair wise comparison of availability in more sizes and remaining customer requirement parameters**

I	II	I	II		
Availability in more sizes	More comfort	3.65	4.01	II	4
Availability in more sizes	Less cost	3.65	4.00	II	3
Availability in more sizes	More life	3.65	3.88	II	1
Availability in more sizes	No color change	3.65	3.51	I	1
Availability in more sizes	Good elastic behavior of cloth	3.65	3.61	I	1
Availability in more sizes	No harm to skin	3.65	3.63	I	1
Availability in more sizes	No wobbling	3.65	3.57	I	1
Availability in more sizes	Hot in winter and cold in summer	3.65	3.60	I	1
Availability in more sizes	Less time to dry after washing	3.65	3.16	I	5
Availability in more sizes	No effects of cuts	3.65	3.79	II	1
Availability in more sizes	Rain resistant	3.65	3.34	I	3
Availability in more sizes	Sufficient air passing	3.65	3.40	I	2
Availability in more sizes	Availability in more colors	3.65	3.42	I	2
Availability in more sizes	Availability in more patterns	3.65	3.55	I	1
Availability in more sizes	Easy availability	3.65	3.54	I	1
Availability in more sizes	No cracking in	3.65	3.52	I	1

more sizes	material				
Availability in more sizes	Permanent stitching	3.65	3.35	I	3
Availability in more sizes	Modifications to change size	3.65	3.28	I	4
Availability in more sizes	No effects of cuts	3.65	3.79	II	1

After comparison between *availability in more size* with the all other customer requirement parameters, comparing more comfort and other remaining customer requirement parameters, the average scores are from the Table above and the intensity was filled by a company expert which is repeated as soon as all pair wise comparisons complete. The results of pair wise comparisons were, then, fed to the *super decision software* from which weights or priorities of the customer requirements were obtained. The details of results obtained which shows in Table

**TABLE 6: Priority Values for CRP**

S.No.	CRP	Corresponding Priority values
1.	Availability in more sizes	0.049
2.	More comfort	0.156
3.	Less cost	0.150
4.	More life	0.115
5.	No color change	0.034
6.	Good elastic behavior of cloth	0.044
7.	No harm to skin	0.045
8.	No wobbling	0.038
9.	Hot in winter and cold in summer	0.041
10.	Less time to dry after washing	0.011
11.	No effects of cuts	0.084
12.	Rain resistant	0.024
13.	Sufficient air passing	0.026
14.	Availability in more colors	0.025
15.	Availability in more patterns	0.037
16.	Easy availability	0.038
17.	No cracking in material	0.035
18.	Permanent stitching	0.021
19.	Modifications to change size	0.017
<b>Inconsistency = 0.0153</b>		

It also shows that the value of consistency ratio is within the permissible limits ( $0.0153 < 0.1$ ).

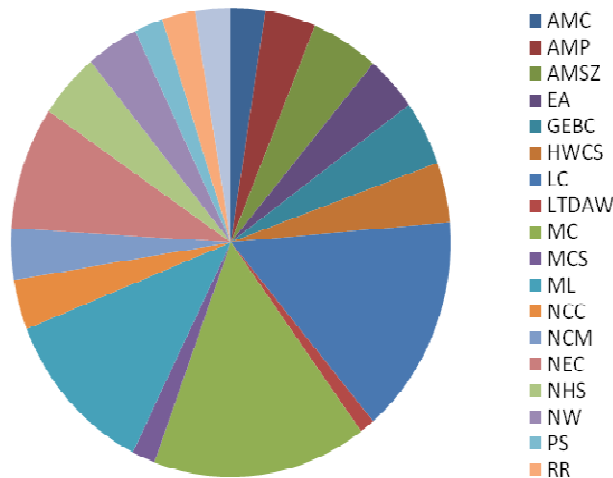


Fig. 2. shows the contribution of each parameter to the goal, below

Next step was the conversion of customer requirements into product requirements. For this conversion, each technical requirement should be measurable and global in nature and should satisfy the voice of the customer

In this Paper, eight important quality characteristics were considered to meet customer requirements. These were *performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality*. All of these quality characteristics are explained below: In the next step, Interrelationship matrix was drawn, which was accomplished by experts of the concerning field. This interrelationship matrix shows the belongingness of the customer requirements to the product requirements (for Strong -9, Medium -3, Weak-1)

Table 7: Interrelationship between product requirements Parameter *performance* with CRP

PERFORMAN CE	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Expert 11	AVERAGE
Availability in more sizes	1	3	1	3	3	1	1	1	1	3	3	1.9
More comfort	9	3	1	1	3	3	3	3	9	3	3	3.7
Less cost	1	3	3	1	9	3	3	1	1	3	9	3.3
More life	3	1	3	9	9	3	3	3	1	3	3	3.7
No color change	3	1	3	1	3	1	3	1	3	9	3	2.8

Good elastic behavior of cloth	1	3	3	1	3	1	3	1	3	3	1	2.0
No harm to skin	1	3	3	9	9	3	3	3	1	3	3	3.7
No wobbling	1	3	3	1	3	1	3	1	3	9	3	2.8
Hot in winter and cold in summer	1	3	3	1	3	1	3	1	3	3	1	2.0
Less time to dry after washing	1	3	1	3	3	1	1	1	1	3	3	1.9
No effects of cuts	1	3	1	3	3	1	1	1	1	3	3	1.9
Rain resistant	1	3	1	1	3	3	3	3	9	3	3	3
Sufficient air passing	1	1	3	1	9	3	3	1	1	3	9	3.1
Availability in more colors	1	1	3	9	9	3	3	3	1	3	3	3.5
Availability in more patterns	1	1	3	1	3	1	3	1	3	9	3	2.6
Easy availability	3	1	3	1	3	1	3	1	3	3	1	2.0
No cracking in material	1	3	1	3	3	1	1	1	1	3	3	1.9
Permanent stitching	9	3	1	1	3	3	3	3	9	3	3	3.7
Modifications to change size	1	3	3	1	9	3	3	1	1	3	9	3.3

After getting Interrelationship Values Next step is to draw *The Quality House Data Processing Table*. This table was being drawn, using average values of responses from the Interrelationship matrices filled by various experts of the field. In this the weights of customer requirement parameter are multiplied by respected column and then absolute important values are obtained as shown in Table

## 5. CONCLUSION

Following are the conclusions of the research work:

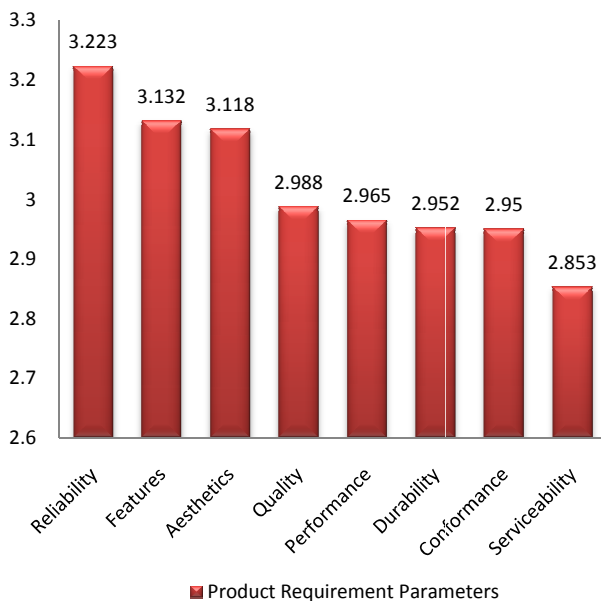
- After getting final results, it was concluded that still today the choice of a middle class person is reliable product, and not the product of different features and aesthetic looks. The reason behind that still today our country is having about 70% middle classed job/business oriented middle aged people who are still using the garments to fulfil their basic clothing needs.
- It is also concluded that because of modernization of the cities parameters *features* and *aesthetics* have almost equal importance for most of the customer. On one side customer wants features in the product, at the

same time, he also wants his belongings should be attractive.

- For today's customer, quality, satisfactory performance of the product, durability of product and conformance of the product to the standards is of equal importance.
- It is also concluded that the parameter serviceability is least preferred by today's customers because of rapid changing demands of market.

**TABLE 8: Ranking of Product Requirement Parameters**

S. No	Product requirement parameters	Weighted sums	Rank
	Reliability	3.223	1
	Features	3.132	2
	Aesthetics	3.118	3
	Quality	2.988	4
	Performance	2.965	5
	Durability	2.952	6
	Conformance	2.950	7
	Serviceability	2.853	8



**Fig. 3. Graphical interpretation of the results**

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# Linkages between Critical Success Factors and Performance Measures for Improvement in Service Quality

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**Abstract:** This paper tries to link the Critical success factors and Performance Measures for improvement in Service Quality in Life Insurance sector. An instrument for identifying the problem through analysis of facts in order to gain thorough, proper and clear understanding has been designed. The linkages both strong and weak will be established from the empirical study. The result will help in deriving a statement in which a predicate affirms or denies something about the subject for further study and research for services to be provided in Life Insurance sector. The authors hope that this paper will help companies in better understanding of Service Quality management and improvement practices to meet the needs of the organization.

**Keywords:** Service Quality, Organizational performance, Pilot study, Life Insurance sector

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## 1. INTRODUCTION

Life Insurance sector in India has witnessed a sea change in past 100 years. An almost 250 plus insurance company operating in India before 1937 were merged to form “Life Insurance Corporation of India” (LIC) and is still a statutory body totally undertaken by the Govt. of India. Post liberalisation in the economy in 1991, gates were again thrown open for investment in this sector for the private players, both national and foreign partners (Insurance companies). In case of joint venture with Indian partner the FDI limit was set to 26% for foreign partner (IRDA, 1996). 26 Indian and foreign private Companies started their operations post year 2000 (IRDA, 2013).

As observed in many industries, the incumbent had always faced problem whenever the sector has been opened for the private players. The new entrants with their sound financial backup, advanced technological support and through extensive research and proper and correct understanding had felt it much easier to grow and prosper. Interestingly this didn't apply to Indian life insurance sector and LIC still continues to dominate even 17 years after the opening-up of the sector for private players. Also the private players were required to expand quickly for their need to beat the competition and they were quite aggressive in it. They however failed to realize the high upfront cost associated for their expansion. Their breakeven, which was expected to be 10 years, has risen to 20 years now. To add to this

they are now facing the problem of dwindling volumes as policy lapses are increasing every year. As India is a price and quality sensitive market, the competition has grown two fold for the private players. The premium rates have plummeted and have made it imperative for the insurance companies to work on thin profit margins. They need to do something extra but ordinary what the incumbent has failed to do during its (monopolistic) operation in India in last 75 years. It can either be in terms of product innovation or better services to the customers. They need to differentiate themselves from competitors so that they grab or seize a bigger share in Indian Insurance market.

Primary investigations revealed a number of reasons behind this sharp fall of premium income. They were incomplete information of the facts, miss-selling by the agents, non-cooperation by the company staff, exorbitant policy charges, claim settlement issues, wrong promises made by the companies, attrition rate of employees, closure of branches, and technological use by the companies to address the grievances, cultural issues etc.

To find a solution to the present problem, the authors tried to critically analyze the research studies done so far in the life insurance sectors in India. Wide range of products in offerings in markets by these companies led the authors to think on the service dimension and forced them to think how improvement in quality of services to customers will help companies' in their objectives. To deal with various

threats the authors tried to understand the different measures needed to allow speedy utilization of service improvement tools and technique and the predominant or critical factors that prevent them as service yields intangible and more customers contact.

This paper develops Critical Success Factors and Performance Measures framework using the facts revealed through survey, secondary data specific to Life insurance Industries and detailed contemporary studies reported on Service Quality in insurance Industries and other service sector Industries .This paper provides a synthesis of the Service Quality literature by identifying nine critical factors (areas) and 4 Performance measures of Service quality management in a business unit. This was possible after thorough review and collection of the Service Quality success factors and Measures of Performance literature that is being and must be practiced to achieve Service Quality improvement in insurance companies. Operational measures of critical factors and Performance Measures are developed that can be used to produce a profile of companywide Service Quality improvement and management requirements. To check the content validity, construct validity and reliability, data was collected as responses from 8 companies consisting of 3 business heads, 4 zonal managers, 8 regional managers, 16 area managers, 16 branch managers, 32 sales managers, 40 agents and 474 customers. SPSS was used for analysis of the data.

The Critical factors and Performance measures used were at all the levels in the organizations to check the Service Quality practices being followed and implemented. The measures were found to be both valid and reliable. The paper aims at identifying and linking Critical Factors and Performance measures for Service Quality improvement in Life Insurance sector and designing and testing an instrument affecting Service Quality

The next section briefly reviews the Service Quality literature and identifies critical factors and Performance Measures of Service Quality that emerge from the literature. The process of developing the measurement instrument is then described. Finally, the measures are examined along with the psychometric properties and the results and conclusions are given.

## 2. LITERATURE REVIEW

Around the second half of the 20th century, quality debate shifted from Product quality to Service Quality, as service operations became more important than manufacturing. Regan (1963) was the first to recognize that service operations are distinctive in nature from product manufacturing. He claimed that “intangibility”, “perishability”, “heterogeneity” and “simultaneity” made total comprehension of services difficult. These four characteristics were also cited and agreed by Sasser et al. (1978); Zeithaml et al. (1985); Fisk et.al(1993);

Parasuraman et.al (1985). They all argued these four well documented characteristics must be acknowledged to recognize or admit the existence, truth and reality for the full understanding of service quality. Subsequently there was a growing support for using the SERVPERF instrument as the method was based on the performance based paradigm of perceptions only measures, whereas the SERVQUAL instrument was based on disconfirmation paradigm of perception minus expectations measures. With the existing SERVPERF instrument being developed to measure service quality in a business to consumer context; it is recognized that Service Quality determinants and Service Quality items are needed to be added to evaluate Service Quality in business to business environment. Mashhadiabdol et.al ( 2014).

Combining the research, Parasuramanet. al (1985); Zeithaml et al(1990); Westbrook & Peterson (1998) and Gronroos (2000), with the outcome of the workshops conducted by them, it was agreed that Service Quality of Business Support services should be evaluated using 15 Service Quality determinants:Reliability, responsiveness, competence, Courtesy, credibility, security, access, communication, understanding, tangibles, assurance, clout, demographics, price, product offering, geographical presence.

## 3. THE RESEARCH PROCESS

### *Subjects and Measuring Instrument*

Since the measuring instrument was developed for Insurance companies, Management, Agents and Customers were the prime focus of study. The Service Quality practices adopted by the company, adapted by the Managers and Agents and perceived by the Customers were studied. The gap between Customers perceived Service Quality and received by them were analyzed. Since the objective was to develop a measurement instrument that could be used in service operations of very big companies, firms with minimum customer base of ten thousand customers and with at least 20 Managers and 100 plus Agents were taken into consideration. The managers were interviewed personally, the agents were explained the necessity of this study. The customers were invited at the local branch offices for meetings and their concerns and expectations were recorded. As time period was not limitation it was possible to meet all of them.

The purpose of this research was to correlate the Service Quality Critical factors and Measures of Performance. This correlation was checked after the constructs were both found to be Reliable and valid. 81 organizational requirements for effective Service Quality practices and 9 constructs from 81 organizational requirements were generated from the literatures that represented 4 different Performance Measures with 26 factors of quality and productivity improvement approaches. Judgmental process

of grouping similar requirements led to the classification of all these eighty one and twenty six requirements into nine and four separate categories. Categorization was used to development of individual items. This process resulted in an instrument strongly grounded in a literature. The eighty one requirements were termed as independent variables and the 26 variables were termed as dependent variables. The model proposed by Shrivastava, Mohanty and Lakhe (2006) was taken into consideration for this study.

The independent variables are "service quality improvement approaches" and "productivity improvement approaches". The dependent variables are the outcome derived from those independent variables. Actual figures and percentages were used to evaluate company performances, such as percentage of defective processes, employee turnover rate, company sales in terms of premium generated, etc. Fig.1 suggests Structural Coefficients of the Derived Service Quality model for Life Insurance sector in India. Table 1 & Table 2 show the Physical significances of Critical factors and Performance measures.

A doctrine that combined the characteristics of performance measures was used that ensured process output. Factor analysis was carried out to check the content reliability and validity along with multiple regression analysis to check the correlation. Multiple correlations checked the minimum number of input variables that strongly related to the output variables. While the nine factors were literature based its, validation was done by empirical research. Reliability and validity were demonstrated to be high that were intended to

measure. Other set of critical factors or different factors could have been developed but the set of factors developed appeared to capture most of important aspects of effective Service Quality dimensions as thought by researchers. Empirical research overtime ultimately determined the validity of those set of Performance Measures.

The internal consistency method is the most general form used to assess the reliability of a set of measurement items indicating the constructs. Inter correlated and homogeneous measurement items are considered to be highly reliable constructs. Cronbach's alpha ( $\alpha$ ) is the most widely used reliability coefficient for measuring internal consistency. Subset having the highest reliability coefficient is likely to be the best construct with regard to internal consistency (Saraph et al., 1989). To ensure internal consistency, the minimum value of  $\alpha$  should be at least 0.6 (Nunnally and Bernstein, 1994). All factors were found having alpha value more than 0.6 which concluded that the scales developed were found to have expected reliability. Measures were found to have high degree of Criterion validity when taken together. The coefficient found were 0.959 for Critical Factors and 0.914 for Performance Measures. Construct validity was required to measure the extent to which the items in a scale all measure the same construct. The item-score to scale-score correlations were used to determine if an item belong to the scale as assigned, belongs to some other scale, or if it should be eliminated. If an item did not correlate highly with any of the scales, it was eliminated. Nunnally (1978) (Eigen value should be more than one for construct validity)

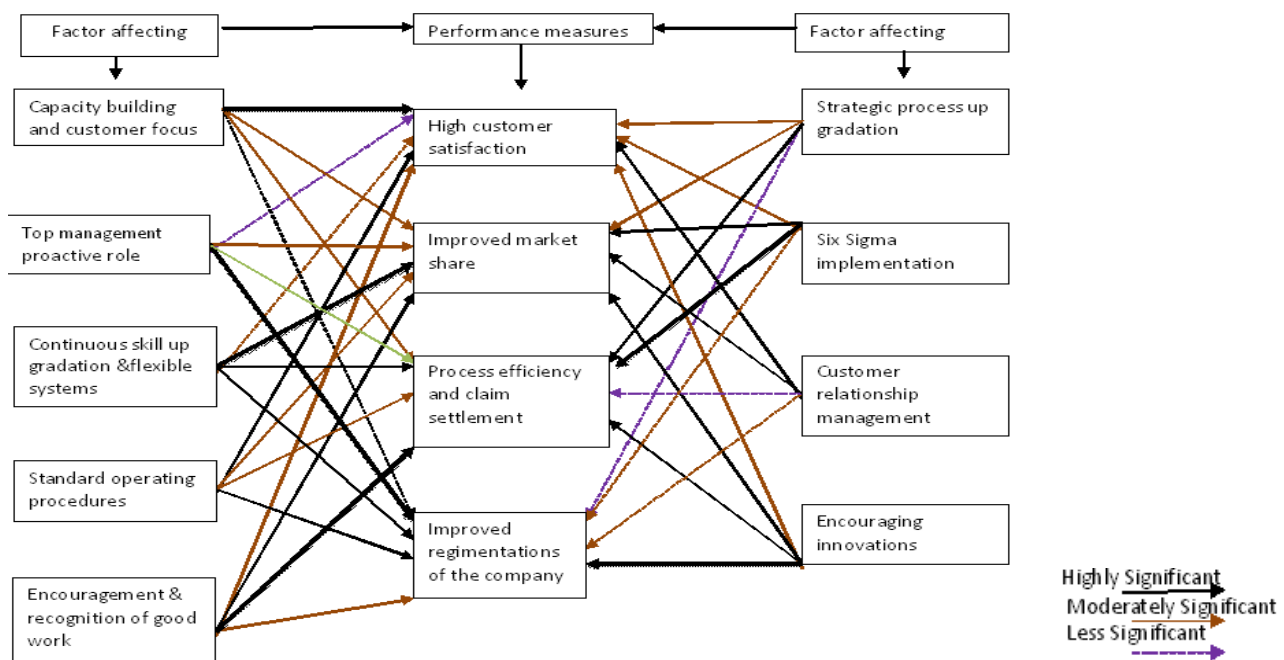


Fig. 1. Structural Coefficients of the Derived Service Quality model

**TABLE 1: Critical factors and their physical Significance**

Sr. no.	Critical factors for Service Quality Improvement	Explanation of Critical Factors
1	Capacity building and customer focus	Identifying customers' requirements by paying personal attention to their needs and building capacity to fulfill it.
2	Top managements proactive role	Creating measurement system, commitment to resource allocation, customers feedback analysis based on measurement system.
3	Continuous skill up gradation and flexible system	Availability of relevant infrastructures of Six Sigma project implementation. Training.
4	Standard operating procedures	Problem solving ability of workforce. Change management.
5	Encouragement & Recognition of good work	Encouraging cooperative behavior and attitude.
6	Strategic process up gradation	Continuous process monitoring and improvement. Strategy definition by senior management. Goal setting by senior management.
7	Six Sigma implementation	Optimum time for implementation of Six Sigma.
8	Customer relationship management	Training of resource persons (Six Sigma trainer). Prompt attention to customer's complaints. Involving customers in Six Sigma projects.
9	Encouraging innovations	Encouraging and innovating in regular job work. Product affordability. SWOT analysis.

**TABLE 2: Performance measures: Physical significance**

Sr. No.	Performance Measures for Service Quality Improvement	Explanation of Performance Measures
1.	High Customer satisfaction	Flexible work system, End to end service provision for the customers, Improved returns on investment, Better understanding of customer needs.
2.	Improved Market share	Increased market share , Better product mix in the market
3.	Process efficiency and claim settlement	Cost of work is drastically reduced, optimum utilization of time, Amicable and speedy claim settlement, High process efficiency
4.	Improved regimentations of the company	Robust atmosphere in the company premises

#### 4. ANALYSIS AND RESULTS

This explains the total Variance. Component 1 accounted for 31.031 percent of the total 100 percent of 81 critical items taken simultaneously. Similarly component 4 and component 9 contributed to 6.35 and 3.09 percent of 100%. The authors had taken 9 factors which constituted 77.69 percent of the total hundred percent cumulatively. This was done on the basis of literature review and worldwide acceptance of Scree plot for such type of study. Scree plot suggested that those components which cumulatively constitute 50 percent of the total can be taken as the remaining other components do not have significant contribution towards the study and may be discarded. However the authors chose to go upto 80 % representation of the components which included 62 items out of 81 items under consideration The same theory applied for Performance measure also. Analysis showed that the first

four components were considered for study constituting 21 out of 26 items which accounted to 62.515 percent of the total 100 percent of all 26 items taken together. Also the Factor matrices taken were uni-factorial and were having Eigen values greater than 1. That indicated that all the scales taken in the study in the form of questionnaire had construct validity. SPSS was used to do all the above analysis.

The nine critical factors of Service Quality measures and the four measures of performance in a business unit had criterion-related validity if these measures (collectively) are highly and positively correlated with Service Quality performance in a business unit. The criterion-related validity of the combined set of nine measures of Service Quality management was evaluated by examining the multiple correlation coefficients computed for the nine measures and a measure of business unit Service quality

performance management. Four measures of Service Quality performance were obtained from the sample of Managers, Agents and Customers. Each of them was asked to rate (on a 5-point scale) the Service Quality performance of their division for the past ten years and customer satisfaction with Service Quality for the past five years. Subjective measure was chosen over an objective measure because of the simplicity in identifying and obtaining a subjective measure that would be appropriate for the different types of respondents. The multiple correlation coefficient of the Service Quality performance measure and the nine measures of quality management was 0.9 and 0.8 for 4 Performance measures indicating that both of them have a high degree of criterion-related validity when taken together.

Figure 1 clearly defined the relationship between Critical factors and Measures of Performance. All the critical factors and measures of Performance having  $P < 0.05$  were considered to have strong relationship. Those factors between  $P \geq 0.05$  to 0.3 were considered to have moderate significance and equally moderate relationship and all the factors having significance  $P \geq 0.3$  were considered to have weak relationship and were termed as Less Significant. We can clearly see that Critical Factor 1 (Capacity building and Customer focus) have strong relationship with Factor 1 of Performance Measure (High Customer Satisfaction), moderate relationship with Factor 2 (Improved Market Share) and Factor 3 (Process Efficiency and Claim settlement) and weak relationship with Factor 4 (Improved Regimentations of the company). Similarly all the other Critical Factors and Performance Measures were related to each other. Regression analysis was carried out. The relationships were presented. Coefficients for the CSF's and Performance Measures were summarized. Here the Unstandardized Coefficients were taken as the standard data was ignored following to the different responses given by different respondents.

## 5. EMERGENT IMPLICATIONS

This study is found to be important to the four categories namely: Practitioners, Professionals, Academicians and Industry. All the learning outcomes of the study will be focused primarily on these four categories for all the Measures of Organizational Performance.

### **PROFESSIONALS**

Emergent Top and Middle Management Professionals should show their commitment towards Service Quality practices and take decisions judiciously for motivating other associated staff by encouraging them to participate in Service Quality initiative. They need to train both their field and office staff for Service Quality improvement practices to be integrated into all business functions within the company and to improve specific processes that are critical-to-quality. For deeper understanding of customers Service

Quality perception and evaluation the professionals must focus on the three attributes of Services: (1) Search attributes, (2) Experience attributes, (3) Credence attributes. They need to understand the organizational gaps which fall under their responsibility. These gaps may be difference between Customers Quality determinants and their perceptions about customers' expectations, between their Quality determinants and service specifications, expected to actual delivery of service and lastly a very important area as to what is being communicated externally by the customers about company's service quality initiatives and practices as it has an enormous impact in shaping customer expectations.

### **PRACTITIONERS**

The Service Quality practitioners need to demark the level of improving the service quality in their service areas to fulfil the service gaps and improve upon those service dimensions that contributes to service quality management. The practitioners should understand and realize market segments, customer preferences, customer needs and develop resembling solutions to bring flexibility in service delivery process. They need to measure service processes performance in physical terms (time, cost, profits) and identify components and processes in which the variations should be reduced, minimized or removed which can shape customers' expectations.

### **INDUSTRY**

The companies can shape and contribute to customers' expectations by ensuring consistency in services provided which in long term will lead to its acceptability by the customers. A key to strong service performance for ensuring consistency in services from the companies would be their knowledge and competence supported by reliable and assured information systems. An appropriate organizational structure, system of standards, Education and training plans and their development and results utilization, Linkage of analytical methods and intrinsic technology, Methods for measuring and grasping effects for controlling the Service Quality, temporary and permanent measures for evaluation of effective and efficient implementation of service quality practices, and employee involvement is required to be framed.

### **ACAMEDICIANS**

Service Quality practices have now become a major focus area for Academicians. The findings revealed through this pilot study will help academicians in understanding the policy requirements of the companies, Organizational bindings, standardization of procedures required for specific industry, Status of understanding and utilizing the Human Resources, Grasping of the status of customer satisfaction, Linking of analytical methods and intrinsic technology, Methods for measuring and grasping effects; -

Customer satisfaction and employee satisfaction, - grasping and coping with changes in customer requirements and assessment of firms' current quality management practices.

## 6. CONCLUSION

Such measures could be used by policy and decision makers in an organization to assess the status of Service Quality Management in order to direct improvements in the Service Quality area. This paper will not only allow the Managers and agents to understand customers' needs and requirements (perceptions and expectations) about the services and its quality but will encourage them to implement practices they thought to be unimportant for running their business. Also the customers will understand the difficulties faced by the companies in fulfilling their expectations if all the Service Quality critical factors are considered by the companies for implementation to improve customer satisfaction. The initial results concerning the measures were not as encouraging as gestation period normally is 6 to 12 months is life insurance business but showed tremendous return in long course and revealed customers faith and trust towards the companies. To corroborate the results for further improvement and to the increase the customer base companies need to do a great deal of further research in Service areas. Sample size should be higher. The authors hope that this paper will help companies in better understanding of Service Quality management and improvement.

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# A Taguchi Approach on Influence of Graphite as an Extreme Pressure Additive on the Performance of Lithium Grease

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**Abstract :** Graphite is an extreme pressure additive which improves load carrying capacity of greases. The lithium grease is smooth in appearance, exhibit good water resistance property and good shear stability at high temperature. Graphite particles with different particle sizes and percentage volume by proportion are mixed with lithium grease and influence of graphite powder as an extreme pressure additive on the performance of lithium grease was identified. Graphite particle sizes and percentage volumes by proportion were considered as performance variables and weld load as response. Design of experiments was done by Taguchi method and as per L9 orthogonal array nine experiments were conducted. Experiments were conducted on four ball tester machine with ASTM D 2596 Extreme pressure standards. Signal to noise ratio analysis is done to identify the levels which will exhibit optimum weld load. Mean signal to noise ratio was evaluated to identify levels of particle size and percentage proportion by volume of graphite powder in lithium grease which results in optimum weld load. Analysis of variance (ANOVA) was done to identify significant factor which affects weld load. On the basis of ANOVA it was found that particle size of graphite contributed more than percentage volume proportion in lithium grease for load carrying capacity. On the basis of signal to noise ratio analysis it was found that graphite powder with particle size 0.5 micron and 5 % in proportion by volume in lithium grease exhibited highest load carrying capacity than other combinations.

**Keywords-** Four Ball Tester, Extreme Pressure additive, ASTM D 2596, ANOVA

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## 1. INTRODUCTION

Greases are semi-solid substances composed of lubricating oils and soaps or thickeners. Soaps of lithium, calcium, sodium, aluminum are commonly used thickeners. Greases are popularly used as lubricant; however without additives greases cannot fulfill particular application lubrication requirements. For heavily loaded applications graphite can be effectively used as an extreme pressure and anti-wear additive in greases. The grease should have consistency to carry load during bearing operation and should not thin during entire operation cycle (Antony et. al., 1994) . The lithium soap grease is resistant to water and oxidation. The lithium soap grease shows good shear stability at high temperature

The optimal concentration exist for molybdenum di sulphide and graphite in liquid or paste lubricants. Less than this concentration of solid lubricant is insufficient to maintain protection against wear. The effectiveness of lubrication with solid lubricants will depend on the formation of a complete film protecting the surfaces (Bartz, 1971). Graphite existed on the rubbing surfaces stably and formed composition film with the oil-soluble additives (Chu et al., 1997). Both molybdenum di sulphide and graphite individually improve the anti-wear and extreme pressure characteristics of lithium and organo clay base

greases. Combinations of molybdenum di sulphide and graphite had been found to exhibit synergistic effect in extreme pressure and anti-wear characteristics. However, the synergism depends on ratio of two components and type of grease( Antony et al., 1994). Wear resistance and load carrying capacity of paraffin oil can be improved and its friction coefficient can be decreased by the addition of the graphite nanosheets. There is an optimal content of graphite nanosheets in the lubricating oil, which gives the highest maximum nonseized load and antiwear ability (Huang et al., 2006).

The tribological properties of poly tetra fluoro ethylene (PTFE) (Reick, 1973), molybdenum disulfide (Gansheimer et al., 1973), titanium oxide (Hu et al., 1998) as lubricant additives had been investigated. Additives in lubricants influence tribological properties (Petrushina et. al., 2000, Waara et. al., 2001, Neyman, 2002, Rastogi et. al., 2003, Choa et.al., 2006). Nano particles size lubricant additives also enhance tribological properties . (Alberts et. al., 2006, Wu et. al, 2007).

From literature, it was found that most of study of influence of graphite as an additive in greases was only based on optimal concentration of graphite in liquid lubricants and greases. The aim of this work was to identify optimal concentration as well as optimal particle size of graphite as

an extreme pressure additive in lithium grease. The particle sizes of 0.5 micron, 1 micron and 1.5 micron of graphite was mixed in lithium soap grease in different volume concentrations of 5%, 10% and 15%. A four ball tester was used to measure weld load using ASTM D 2596. Weld load gives extreme pressure performance of grease. It also shows the load carrying capacity of the grease.

## 2. EXPERIMENTAL STUDY

### 2.1 Lithium Grease

Lithium soap grease is smooth or granular in appearance. Lithium soap grease provides water resistant property like calcium soap grease and high temperature property like sodium soap grease.

### 2.2 Selection of Graphite as an additive

For greases, additives enhance the existing desirable properties or suppress the existing undesirable properties and impart new properties. During selection of additive it is considered that the additive should be inorganic compound because inorganic compound shows excellent tribological properties. Along with inorganic compound the other most important consideration is that solid lubricant shows better tribological properties at extreme conditions. From the objectives of research graphite was selected as an extreme pressure additive.

### 2.3 Design of Experiments

Design of experiments was done on the basis of Taguchi technique. The purpose of this research was to identify optimum particle size and percentage concentration of graphite by volume in lithium grease on extreme pressure (EP). Therefore, particle sizes of 0.5 micron, 1 micron and 1.5 micron of graphite are used along with combination of 5%, 10% and 15% concentration of graphite by volume in lithium grease. Factors and their respective levels are listed in Table I.

**TABLE I: Factors and their levels**

Factors	Level 1	Level 2	Level 3
Particle size (micron)	0.5	1	1.5
Percentage concentration by volume	5 %	10 %	15 %

### 2.4 Four Ball Tester Machine

The four ball tester machine TR-30L-IAS DUCOM make was used for tests. ASTM D 2596 standard procedure was followed to find weld loads and wear scar diameter respectively of lithium grease with graphite powder as an additive. Four ball tester machine consist of three balls held firmly in ball pot assembly at bottom and one ball at top

held in spindle collet. Grease sample was put in ball pot assembly along with three balls. The top ball was inserted in collet and mounted on spindle. The ball pot was placed on the antifriction disc. The spindle was made to rotate at desired speed.

### 2.5 Tribological Testing As Per ASTM D 2596 (Extreme Pressure Test)

To determine weld load, testing was done as per ASTM D 2596 standard procedures. Carbon chrome balls of 12.7 mm diameter each were used in tests. The temperature of  $27 \pm 8$  °C and speed of  $1770 \pm 60$  rpm were maintained as per standards. The load as per standards was applied by load lever. The top ball was rotated by the spindle in contact with three balls in ball pot. The motor was run for 10 seconds duration as per standards. Weld point can be detected by noise of motor or sudden drop in pressure. If balls are not welded, it is considered as 'passed load'. In such case, next load as per standards was applied and test procedure was repeated till weld load is obtained. Weld loads for 9 tests are listed in Table II.

Table II shows L9 orthogonal array consisting of nine experiments and three levels of two factors particle size and percentage concentration of graphite by volume in lithium grease

**TABLE II: L 9 orthogonal array and result table**

Test no.	Factors		Weld load (kg-f)*	Signal to Noise Ratios
	Particle size (micron)	Concentration by volume (%)		
1	0.5	5	620	55.8478
2	0.5	10	500	53.9794
3	0.5	15	400	52.0412
4	1	5	500	53.9794
5	1	10	315	49.9662
6	1	15	250	47.9588
7	1.5	5	315	49.9662
8	1.5	10	250	47.9588
9	1.5	15	200	46.0206

*To convert kg-f into newton multiply by 9.806 (ASTM D 2596 Standard)

## 3. SIGNAL TO NOISE (S/N) RATIO CALCULATIONS

Signal to noise ratio is considered as a response of the experiment, which is the measure of variation within the trial when noise factors are present. Weld load was considered as the response as per ASTM D 2596 standards. Larger the weld load larger is load carrying capacity of the



grease, therefore 'the larger-the-better' criterion was considered. S/N ratio was calculated by Eq. I (Ross, 1996)

$$\frac{S}{N} = -10 \log_{10} \frac{1}{n} \sum_{i=1}^n \frac{1}{y_i^2} \quad (i)$$

Where,  $y_i$  is number of response value in the tests and  $n$  is the number of experiments. S/N ratio values for weld loads are listed in Table II

Fig.1 suggest that level 1 of particle size (0.5 micron) and level 1 of percentage proportion (5 %) of graphite as an additive in lithium grease will give optimum weld load.

Average S/N ratios listed in Table III for tests 1 to 9 are evaluated to find out influence of each level of particle size and percentage proportion on weld load. Factor with large difference ( $\Delta$ ) of average S/N ratio means high influence to weld load. Table III suggests that particle size has larger influence on weld load and percentage proportion has larger influence on wear scar diameter.

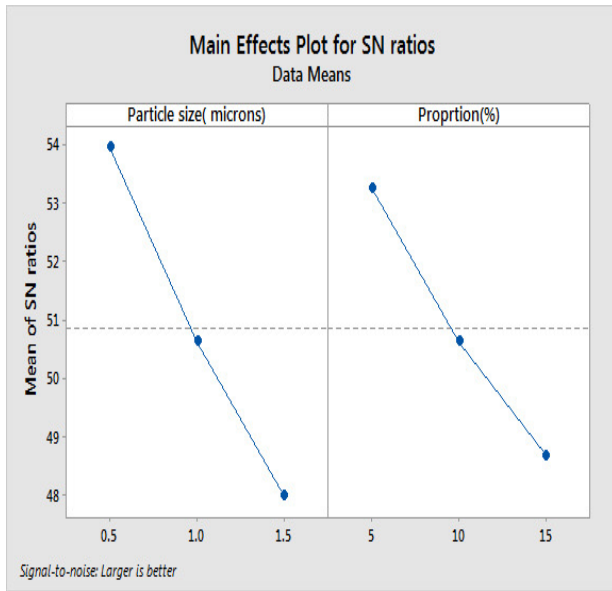


Fig. 1. Effect of factors on S/N ratio for weld load

TABLE III: Analysis of mean for S/N ratios

Levels	Factors	
	Particle size	Percentage proportion by volume
1	53.9561	53.2644
2	50.6348	50.6348
3	47.9818	48.6735
$\Delta = \text{Max} - \text{Min}$	5.9743	4.5909
Rank	1	2

#### 4. ANALYSIS OF VARIANCE (ANOVA)

The analysis of variance was used to establish statistically significant parameters and percent contribution of these parameters on the weld load. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels. First, the total sum of squared deviations  $SS_T$  from the total mean S/N ratio  $n_m$  is calculated as follows (Ross, 1996)

$$SS_T = - \sum_{i=1}^n (n_i - n_m)^2 \quad (ii)$$

Where,  $n$  is the number of experiments in the orthogonal array and  $n_m$  is the mean S/N ratio for the experiment. The Percentage contribution  $P$  can be calculated as (Ross, 1996)

$$P = \frac{SS_d}{SS_T} \quad (iii)$$

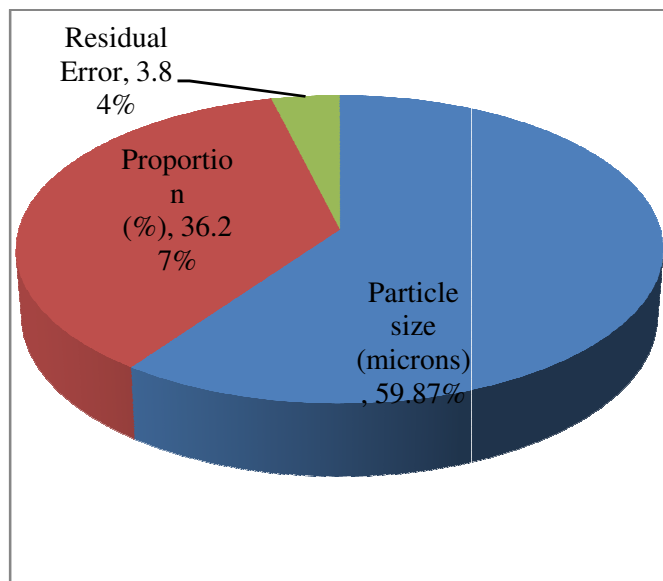
Where,  $SS_d$  is the sum of the squared deviations. The ANOVA results for Graphite are given in Table IV.

The ratio of variance due to effects of a factor and variance due to error term is called variance ratio or F statistic. The significance of factors is determined by F value. The level of significance of each factor is determined by p value or probability value. Factor with lower p value indicate that the factor has larger impact on the outcome of experiment (Ross, 1996). Generally, factors with large S/N ratio have low p value, which indicates that the factor has larger impact on the outcome of experiment

TABLE IV: ANOVA table for the weld load of lithium grease and Graphite as an additive

Parameter	DOF	SS	MS	F-Value	P-Value	P %
Particle size (micron)	2	96339	48169	31.10	0.004	59.87
Proportion %	2	58372	29186	18.85	0.009	36.27
Residual Error	4	6194	1549			3.84
Total	8	160906				100
S = 39.3524 R-Sq = 96.15% R-Sq(adj) = 92.30%						

From Table IV, particle size of graphite has lower p value, which indicates that particle size has larger impact on weld load. Fig. 2 shows, for graphite as an additive particle size gave more significant contribution of 59.87% than percentage proportion of graphite 36.27% on weld load.



**Fig. 2. Contribution in percentage of factors on weld load**

## 5. CONCLUSION

From the experimental study, influence of particle size and percentage proportion by volume of graphite as an extreme pressure additive in lithium grease on weld load was investigated. Summarizing main features of results as follows conclusively,

1. As per L9 orthogonal array obtained by Taguchi approach, 9 tests were conducted to find weld load of the lithium grease with graphite as an extreme pressure additive adhering to ASTM D2596 standards,
2. Larger weld load is desirable for higher load carrying capacity of lithium grease with graphite as an additive; therefore 'larger is better' is applied for S/N ratio for weld load. S/N ratio analysis revealed that test 1 (0.5 micron and 5 % proportion by volume of graphite in lithium grease) is an optimum combination with larger S/N ratio.
3. S/N ratio analysis also revealed that increase in particle size of graphite in lithium grease decreases weld load. Similarly, increase in % proportion of graphite in lithium grease decreases weld load.
4. In order to find out influence of each level of factors particle size and percentage proportion, mean S/N ratio for weld loads at levels 1 and 2 were computed by averaging S/N ratios for tests 1 to 9. This analysis suggested that particle size has larger influence on weld load as compared to percentage proportion. It was also revealed that level 1 of factors particle size (0.5 micron) and

percentage proportion (5 %) respectively will give optimum weld load.

5. ANOVA results revealed that for graphite as an additive particle size gave more significant contribution of 59.87% than percentage proportion of graphite 36.27% on weld load.

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# Quality Circles for Developing Smart Workers: Revisiting the Relevance of Quality Circles in the Context of Make in India

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**Abstract :** The aim of this paper is to emphasise the unique potential of the Quality Circles as a tool for the overall and all round development of the workers, working in manufacturing organisations and transforming them into a smart and competent resource suitable for the modern world class organisations. The study involving a large sample associated with the Quality Circle activities across the diverse spectrum of manufacturing organisations, brings out that Quality Circles help in all round development of the workforce. Quality Circles develop a scientific and data based approach towards problem solving and empowers the workers with the problem solving techniques for solving the work related problems.

**Keywords:** Quality Circles, Smart Workers

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## 1. INTRODUCTION

As the manufacturing organizations world over are gearing themselves for the world class manufacturing to survive and thrive in the competitive environment, the need for transforming the workforce to meet the new expectations is being felt all the more. In the Indian context, as the country is ambitiously implementing its new initiatives like Digital India, Smart India and Make in India to become a developed nation, its quite imperative that the human resource that is going to make it all happen on the ground, is properly oriented, adequately trained and fully developed.

Quality Circles ( QCs) though a fairly old tool, essentially developed for involving the workers into problem solving and quality improvement across the organization and in the process effect their holistic development, appear to be quite suitable for playing the role of the change agent and catalyst in preparing and developing the workers as needed by modern organizations. Though there are many quality concepts clamouring for attention, apparently competing with, but actually complimenting each other, the quality circles stand taller when it comes to achieving the objective of development of workers.

The present study aims at evaluating the role of quality circles in the overall development of the workforce and identifying the positive changes brought by them. Going a step further it also recommends them as very appropriate tool for the organizations to orient, train and develop their workers as per the need of the times.

## Make in India

The Make in India initiative launched by Government of India in 2014 envisages transforming India into a global design and manufacturing hub. It aims to boost the manufacturing sector by attracting the multinational companies and raising the scale and level of the Indian companies to develop them into Indian multinational companies and to spur the economic growth and create more job opportunities.

Digital India campaign tries change the mindset and to promote conversion of data and also way of working from conventional to digital mode using the technology. While the smart India philosophy focuses on developing creativity and innovativeness among the people and harnessing it for getting the technological solutions for solving the problems of society and industry.

Together all these aim to bring India at par with the most developed and industrialised countries and their ways of working, to build a modern progressive and smart India.

## Relevance of Quality Circles for Make in India

There is a good commonness between these philosophies and the quality circles. At the micro level of a group of workers, working in an organization, quality circles try use, achieve and implement these concepts in their day to work as well as solving their work related problems.

Quality circles in a way, prompts the workers to become digital as in the QCs there is a great emphasis on collecting the numerical data and analysing it rather than going for the gut feeling or rule of thumb. QC necessitates, encourages and rewards the smartness of workers. QC makes the workers to select SMART goals, meaning Specific, Measurable, Achievable, Realistic and Time bound.

Simply put, if the Make in India is to achieve its desired success, the products manufactured in India should of the highest quality and still economical. QC is one of the techniques which helps in achieving both these things.

In some sense India is today where Japan was standing before the quality revolution. In fact far ahead of that. However to realise the dream of establishing a brand of 'Made in India', the country has to go further. QCs have a major contribution in building the brand and reputation of Made in Japan. They have raised the quality and the productivity in Japan to internationally acclaimed level. One of the author visited Japan as a part of the study tour organized by Quality Circle forum of India (QCFI) in 2017. During the tour he visited Toyota and few of its ancillaries to get insight into the Quality circle practices in Japan.

### ***Global Manufacturing Scenario and its Implications***

The global manufacturing scenario is continuously evolving due to technological advancements, emergence of modern management techniques and socio-cultural and geo-political factors. Not just the companies but the countries are competing with each other to get and retain the right share of the pie.

The following characteristics are notable

- Struggle to operate at both global and local level
- Stiff global competition in getting the business
- Short product life and organizational life cycles
- Rapid advances in technology
- Emergence of too many management concepts
- Pressure to deliver very high level of performance
- Constant pressure to increase the quality and reduce the cost
- Need for continuous innovation and value addition
- Stringent environment and safety norms
- Changing composition of the workforce

### ***Role of Industrial Engineering***

Industrial engineering has a great potential to offer the solutions to the problems in industry and business. It provides a big basket of tools and techniques to address the

wide variety of problems. In fact industrial engineering as a discipline has evolved to precisely deal with the complexities of the modern industrial and business activities. It encompasses all the domains of organizational functions and activities and bridges the gap between the approaches of the managers and engineers. It blends the technical and management disciplines seamlessly and contains and retains the best of both the worlds, so to say.

### ***Approach to Achieve Manufacturing Success***

Manufacturing excellence can be achieved by use of the modern technology and the management techniques. Earlier the quality management was one of the sections and functions the organizations, but modern and progressive organizations of these days are built around a strong Quality Management System at the core. Thus if any manufacturing organization is to achieve excellence in its operations, it has to embrace the quality management concepts. These concepts are to be ingrained into the entire organization.

There are two approaches to the organizational excellence, one is to make drastic improvements in the technology and processes while the other is to make companywide and continuous small, small improvements. As both will be required in a longer span of existence, it is better that a combination of both be adopted to suit the organization. In any case it is imperative that the success can only be achieved if the organization has the right human resource.

### ***Gearing up the Workforce***

One of the major bottleneck for achieving the manufacturing excellence could be the workforce. The attitude, knowledge, skill, enthusiasm, motivation, involvement and participation of the workers in the work and organisation are very important. Even the best of the technology and management interventions can not succeed unless the workers are ready to adopt and adapt the change.

If an organization has to give world class products or services for a long period of time, it needs to have the right human resource. It's the human resource that provides the competitive edge to an organisation and nothing else.

### ***Expectations of a World Class Organization from the Workers***

Few of the important qualities needed by the organizations in their human resource are

- Innovative
- Participative
- Problem solving abilities
- Taking ownership of their work
- Capable of implementing the quality management system

- Understanding and fulfilling the customers' expectations

At the same time the worker themselves have a lot of expectations from the job. Workers these days are highly educated, want to use their knowledge and skills and want to learn new things. They don't want to keep doing monotonous jobs but want to have their jobs to be interesting and enjoyable. Some of the expectations of the workers from the job can be listed as below.

#### ***Expectations of the Workers from their Job/ Organisation***

- Enjoyable with scope for creativity and innovation
- Opportunity to use their talent and skills and learn new things
- Training in new areas and scope for development and growth
- Opportunity to contribute significantly in the success of the organisation
- Recognition, rewards and incentives
- Sense of worth and fulfillment

From the above, it becomes apparent that if the organisation has to excel, it has to not only get the workers who fulfill its needs but also has to fulfill the expectations of the workers.

#### ***Quality Circles, the Right Tool for Development of the Workers***

Involving the workers into the problem solving, by forming the groups of 8-10 workers handling similar tasks, termed as quality circles, empowering them with the training in QC tools and problem solving techniques and supporting them throughout the process, is an approach developed in Japan in 1962, termed as Quality Control Circles or simply Quality Circles. The same became quite popular in short period of time and then spread the world over. Even after the advent of many newer philosophies and approaches quality circles are still used by organisations across the world in a big way.

Quality circles bring a range of Technical, Economical and Social advantages and improvements for the individual workers and the organisations.

#### **Benefits from Quality Circles**

##### ***For the Workers***

- Problem solving approach and abilities
- Solutions of the problems faced by them
- Increased safety and ease of working
- Proficiency in using the QC tools

- Positive attitude and high enthusiasm
- Job satisfaction and increased morale
- Recognition and rewards

##### **For the Organization**

- Increased productivity
- Increased quality
- Reduced costs
- Timely delivery
- Higher customer satisfaction
- Improved employer- employee relations

## **2. LITERATURE REVIEW**

Extensive literature survey carried out for finding the advantages of the implementation of the quality circles in the organization. The various positive changes brought by the quality circles in the workers have been commonly accepted and widely reported in the research literature.

Quality circles are one of the key factors which has helped Japan to take not only enhance the quality of its products but to acquire a leadership position in the world as regards the quality. Sathasivam Mathiyalakan and Chen Chung (1996) describe how the quality circles have contributed in improving the quality and productivity of the Japanese companies and helped Japan to become an economic superpower. Identification and solution of production-related problems and finding their solutions using a proper problem solving approach by motivated employees has helped Japan in achieving a defect free production system.

Dong Kyoon Yoo, S. Subba Rao and Paul Hong (2006) mention that with increasing automation, the role of human beings is being downplayed. But human beings are a critical source of improving quality results and empowered employees will increase efficiency and productivity. They display greater initiative and are more willing to change and innovate, the qualities required for competing in the current times.

Due to the increasing pressure towards continuous improvement (CI) and the organizational desire to achieve business excellence, high performance, or to become a world-class organisation drives the adoption improvement initiatives, but choosing the right initiative out of the plethora of improvement initiatives of QM and CI development including quality control circle (QC), just-in-time (JIT), and 5S etc, created and developed in mainly in Japan and USA can be tricky. Natcha Thawesaengskulthai (2010), through research carried out for China, India and Thailand, has suggested the approach to selecting the most appropriate and suitable Quality initiative from the perspective of the organizational and social culture.

As Indian industry comprises of the large proportion of the small and medium scale industries (SMEs) it is imperative that to uplift the quality and productivity of the industry as a whole, the various quality concepts should be implemented in the SMEs too.

An investigation of the hard and soft quality management factors of Australian SMEs and their association with firm performance carried out by David Gadenne and Bishnu Sharma (2009), suggests that factors such as employee training, efficiency improvement, and employee and customer involvement are important in maintaining customer satisfaction and maintaining a competitive edge of the organization.

Increased interactions between nations and increased access to the global markets are being driven by rising consumer demands (Michael H. McGivern, Stephen J. Tvorik, 1997). The challenge to strategic management in such an interdependent and interconnected world is in finding ways of adding value, increasing productivity and driving cost reductions across the entire range of an organization's activities. An organization can not make the best of these opportunities unless it successfully implements a good quality management system.

A study carried out by Steve Brown (1997) shows that the manufacturing firms working with the traditional approach prove to be low performing plants while the ones that are enlightened come up as high performing plants. The enlightened firms see quality as an ongoing, never-ending pursuit of customer satisfaction, rather than as a managerial fad, they have senior manufacturing personnel committed to quality and, they have manufacturing strategies which help to translate external customer requirements into internal operational approaches.

High involvement of employees (Vathsala Wickramasinghe, Anuradha Gamage, 2011) through initiatives like quality circles or TQM, bring a lot of benefits to the organizations like Team work, communication, performance evaluation, empowerment, rewards and recognition, and skill development which bring a significant improvement in quality.

### 3. RESEARCH METHODOLOGY

A survey based research was conceived to assess the benefits of the implementation of the quality circles for the workers in the manufacturing organisation. A lot of interaction with the quality experts and managers was made to get the insight into the quality circle activities and their outcomes.

Through the literature review various benefits to the organisations in general and workers in particular were identified.

To verify these effects of the quality circle the survey method used by developing a research instrument and administering it to the persons involved in the QC activities in the manufacturing industries during the Chapter Level Quality Convention of Quality Circle Forum of India, CCQC 2017 at Nagpur. This survey was conducted for the quality circle teams who had participated in the CCQC 2017 during October 2017.

A questionnaire was designed to seek the opinions of the respondents about the performance indicators of the quality circles. Around 100 responses were collected.

### 4. RESULTS

It has been observed that the following benefits have been derived by the use of the quality circles in the manufacturing industries.

SN	Benefits from Quality Circles
1	Reduction in Cost / Losses
2	Reduction in wastage
3	Reduction in rework
4	Reduction in Accidents
5	Increased Safety
6	Increased Productivity
7	Improvement in Quality
8	On time Delivery
9	Increased Morale
10	Higher employee satisfaction
11	Development of employees
12	Increased enthusiasm of workers
13	Ownership and participation of workers in problem solving
14	Improved relations between workers and management
15	Inculcating quality consciousness among employees
16	Better quality management culture in organization
17	Strengthening of Quality Management System
18	Foundation for implementation of other Quality Initiatives
19	Winning of awards in QC Competitions
20	More Savings and better financial performance
21	Higher profitability of the industry
22	Higher Customer satisfaction
23	Improved reputation of the company
24	Sustainable local, regional and global growth
25	Improved market share

## 5. CONCLUSION

A study was carried out to primarily assess the role of quality circles in developing the workers. The benefits of the quality circles for the workers reported in the literature were studied. A survey was carried out among the participants of the CCQC 2017 in Nagpur using the questionnaire. It has been found that the quality circles have a significant role in bringing out allround development of the workers. Quality circles inspire and enable the workers to increase the productivity, quality and safety of their operations, help in creating positive attitude of the workers, increase their morale and makes them participate actively in the organisational work. QC develops the workers to meet the challenges of world class manufacturing.

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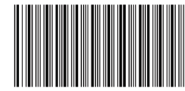
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